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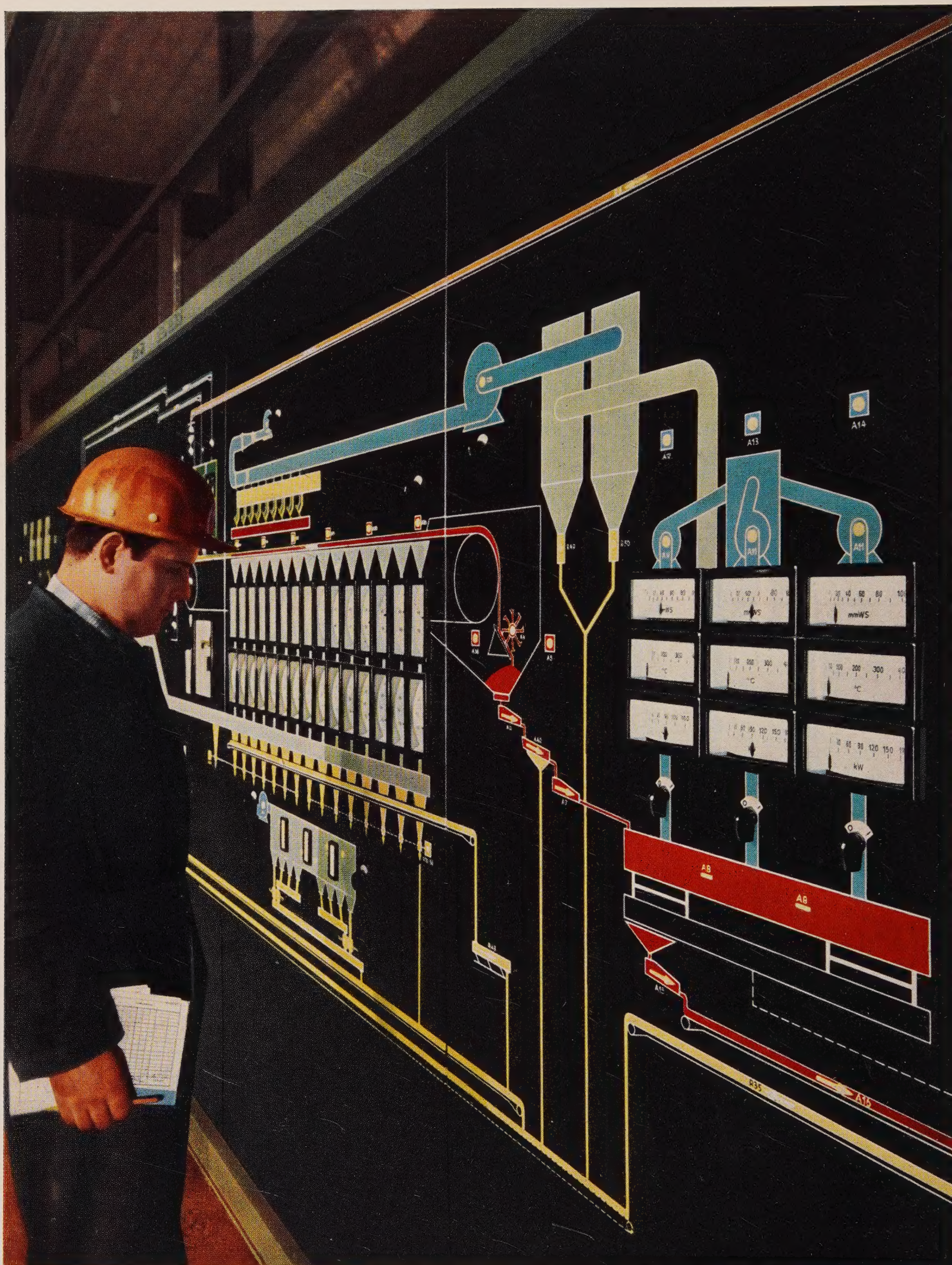
IEMENS REVIEW · VOL. XXVIII · DECEMBER 1961 · NO. 12 · PAGES 387 — 420

CONTENTS



Graphic panel for monitoring and automatic control of a sinter belt plant
(Dillingen steel works)

SIEMENS

REVIEW

SIEMENS & HALSKE AKTIENGESELLSCHAFT · SIEMENS-SCHUCKERTWERKE AKTIENGESELLSCHAFT

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Progress in the Field of Automatic Control Equipment for Large Chemical Plants

BY LUDWIG MERZ*

The remarkable fact that, despite rising prices for raw materials and human labor, the production costs of large chemical plants could be kept within reasonable limits, is due to continuously advancing automation which, in turn, owes its progress chiefly to the development of increasingly efficient control devices.

Another reason for the rapid development of automatic control technology is the necessity of handling extensive and complicated chemical processes with high security. The process variables must be constantly kept on their optimum level. It is, therefore, prerequisite that all physical quantities affecting the process should be automatically controlled.

A third impulse promoting the progress in this field results directly from the two first-mentioned reasons. More than in most other industrial branches, the manufacturers of automatic control equipment must make extraordinary efforts to keep pace with the increasingly exacting demands and to maintain their position in the market in the face of keen competition by always supplying equipment embodying the latest technical achievements.

The functions which must be fulfilled by an automatic control equipment are widely different, depending on whether the process to be controlled is of a continuous or discontinuous nature. Continuous process plants require a less complicated instrumentation, and can be easier controlled, than batch process plants.

Power generation processes, e.g., are inherently continuous. Therefore, automatic control engineering could make its way at a very early date into the boiler room. On the other hand, all chemical processes (similar to processes in the motorcar industry) were originally batch processes. As early as 1912, however, the chemical industries have adopted continuous process methods for large plants. This important and decisive step towards automation was taken several decades before the motorcar industry decided to follow suit.

Automation of continuous processes

The raw material is supplied in a continuous, automatically controlled flow to the various reaction vessels. A characteristic feature of a continuous process is, therefore, the three-dimensional flow diagram. The size of the plant permitting, the measuring instruments and controls are built into the flow diagram (graphic panel) (Fig. 1). In very large plants, however, the great number of measuring instruments might impair the clearness of the display. In such cases, the flow diagram demonstrating the sequence of operations, and in which the measured and controlled variables may be indicated by pilot lamps, is preferably arranged in the form of a frieze above the instrument panels (Fig. 2).

Continuous process control involves the regulation of the raw-material flow between the individual reaction vessels and of the process variables which must be kept on predetermined levels. These process variables may be rates of flow, tank levels, temperatures, pressures, gas contents, *p*H values, etc.

There is a great variety of interrelations between the individual control loops of a plant. Particularly worth mentioning are the recently completed petrochemical plants. For almost a century, bituminous coal tar, a byproduct of coke production, has been used in many countries as raw material of the organic chemistry. In the course of the last years, however, the coal-tar quantities

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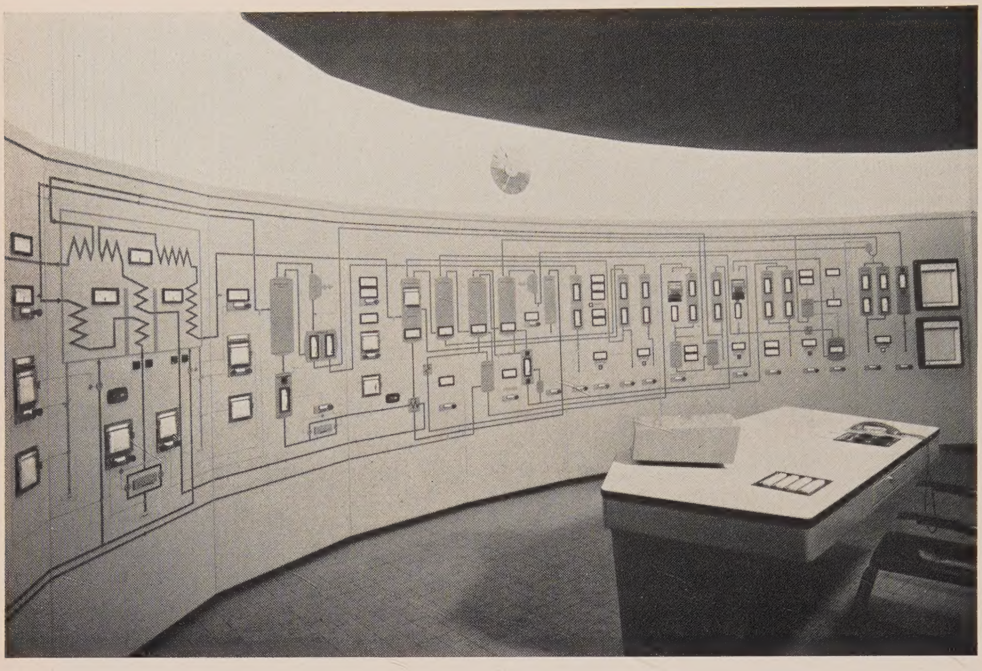

Fig. 1 Partial view of the control room of a chemical plant (flow diagram with built-in instruments)

available have become more and more insufficient for meeting the rapidly increasing demand of the plastics industries. The chemical industries were, therefore, compelled to look for other raw materials of which adequate quantities could be procured. Due to the abundant offers of crude oil from the Middle East, the conditions became favorable. The change-over from coal tar to mineral oil resulted, on the one hand, in a close co-operation between petroleum refineries and chemical works, on the other hand, in the development of new large-scale petrochemical processes.

The necessity of combining various kinds of processing plants and controlling them from a central point, as well as the growing capacity and intricacy of the oil refineries and associated chemical works, led to an increased application of automatic controllers and, consequently, to the necessity of providing larger control rooms. At the same time, it became more and more difficult for the operating staff to take down all the informations supplied by the various measuring instruments and to utilize these informations for correctly adjusting the set points of the controllers. The endeavors to arrange the control room so as to ensure a clear survey of the whole sequence of operations resulted in the following remarkable developments: The measuring instruments and controls were considerably reduced in size, the data required for the management of the plant were cut down to a minimum, and, finally, data handling facilities were developed.

Two of the most important raw materials for the organic chemistry are acetylene and ethylene. In high-temperature pyrolysis plants, light benzenes (by-products of the refineries) are cracked at very high temperatures (about 2,500 °C) into acetylene and ethylene. By an appropriate choice of the cracking temperature, it is possible to vary the acetylene-to-ethylene ratio within wide limits. Fig. 3 shows the automatic control equipment of a large petrochemical plant.

The following figures stated by W. GEISS for a chemical plant designed to produce butadiene from normal butane (n-butane) may serve to illustrate the extent of an automatic control system: Forty-one automatic control operations are provided in this plant for adjusting the physical variables of state; sixty-seven controllers were installed for adapting the cascade-connected devices and machines to the continuous flow of material; and the equipment contains more than one hundred control loops.

If, in the case of combined plants, it is required that both, the refineries and the petrochemical plants, should be supervised from a common central point, the following new problems arise: Bridging of the distances between the extensive detached parts of the plants, equipping of the instrument centers, data handling, and automatic management of the combined plants.

A new departure in the instrumentation of large plants

It is obvious why the users of measuring and controlling equipment call more and more urgently for instruments of similar design which may readily be exchanged. In view of the rapidly increasing number of control loops, this is the only way to keep in stock a reasonably small quantity of stand-by units and spare parts, and, more-

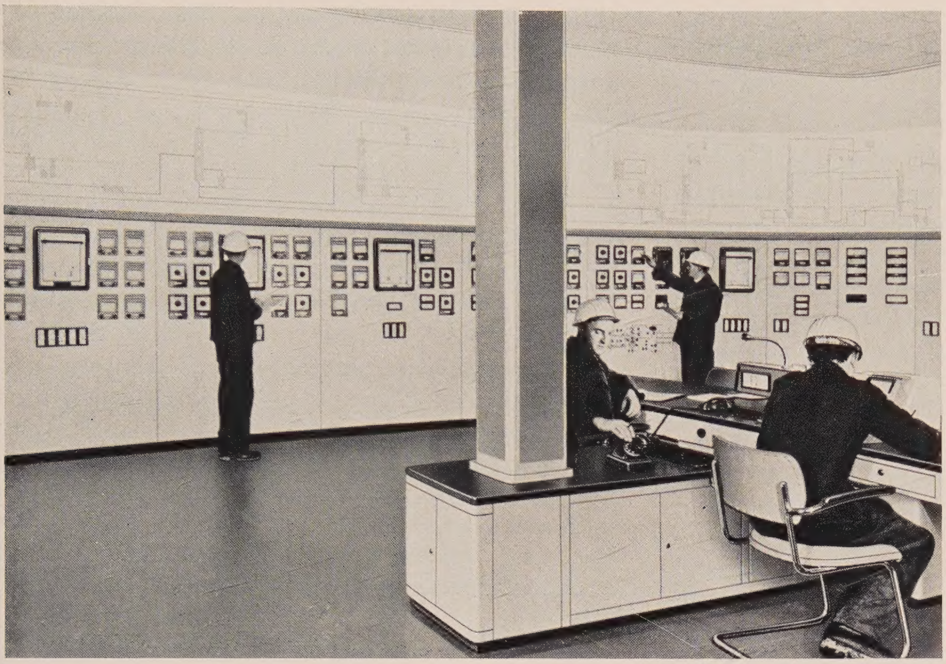

Fig. 2 Control room of a chemical plant (instruments arranged in groups; flow diagram in the form of a frieze above the instruments)

over, to render the equipment adaptable to the requirements of the different processes. The wish of the users coincides with the endeavor of the manufacturers to reduce the number of different types and to increase the efficiency of development work.

The trend in this direction led to the development of so-called standardized subassemblies.

Hence, the progress in automatic control technology is no longer based on the production of special-purpose devices but on the development of a standardized equipment chain whose subassemblies must be very carefully matched with respect to their control features.

The Teleperm*-Telepneu* System has already been dealt with on a previous occasion. Suffice it to say, therefore, that the development of a standardized control system must be preceded by careful investigations for ascertaining what kind of auxiliary energy should be chosen and how the measuring and controlling means of the individual units can be matched correctly, especially with respect to their joint operation and to the different processes to be controlled.

The block diagram of a control loop represented by Fig. 4 shows the most important parts of the equipment

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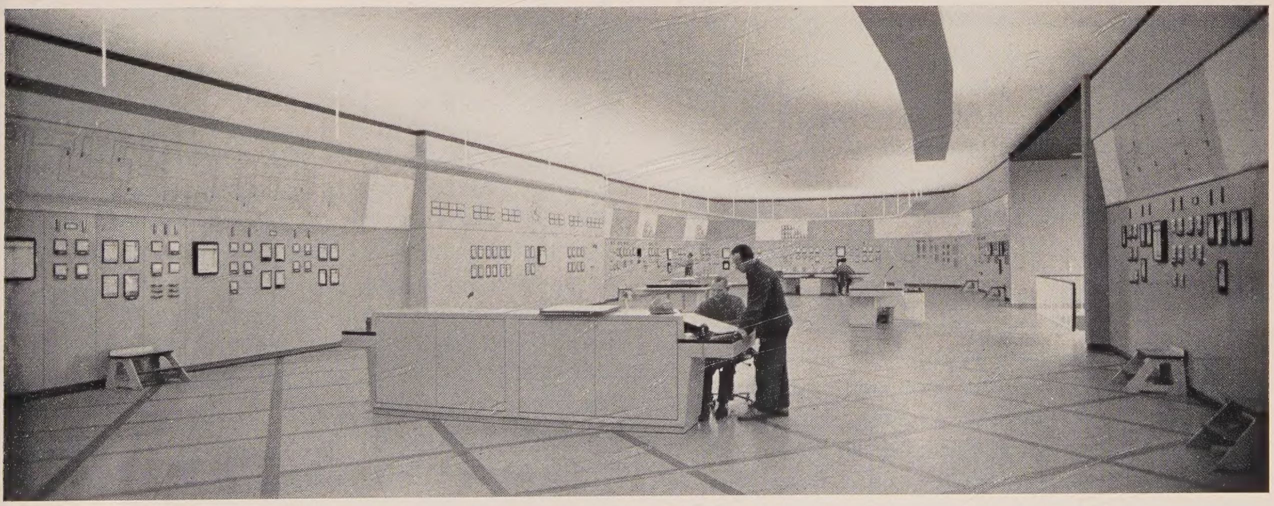

Fig. 3 Instrument center of a high-temperature pyrolysis plant (by courtesy of Farbwerke Hoechst)

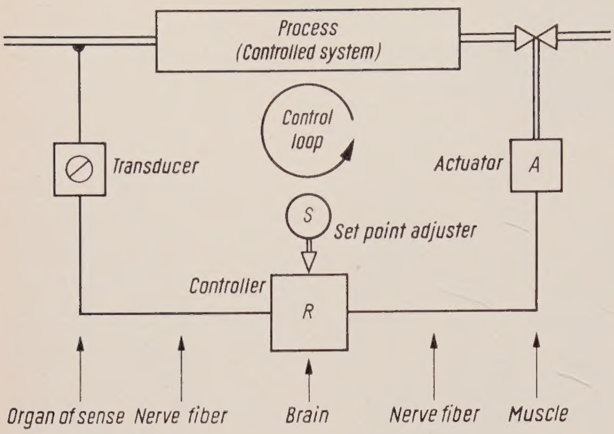

Fig. 4 Control loop and physiological analogies

chain of a standardized control system. The diagram further analogizes the functions of the individual subassemblies of the standardized system with physiological functions. A characteristic feature of a standardized control system is the use of transducers.

The sensors are the "artificial organs of sense" of the control loop. Unfortunately, the signals transmitted by most of the sensors are non-uniform, weak, and hardly suitable for bridging distances. For this reason, transducers are connected to the output of the sensors. These transducers transform the energy received from the sensors in such a way that uniform signals are obtained from the different measured variables. The transducers also function as amplifiers. Their output currents are standardized. As a result, all units connected to their output, such as controllers, recorders, protective circuits, etc., may be of absolutely identical design.

A characteristic feature of the Teleperm-Telepneu System is the fact that it is not restricted to exclusively using either electric or pneumatic power as auxiliary energy, but that the transition from electrically to pneumatically operated devices can take place at any point of the equipment chain. This fact proves to be of particular advantage for the automatic control of chemical process plants. For several decades, electric as well as pneumatic devices have been used in chemical works for process control. Of late years, the electrical units have been supplemented, and their efficiency has been considerably increased, by the introduction of electronic components.

The question which kind of auxiliary energy is the most advantageous has been much discussed up to the present. The most important points to be considered are the following: Safety against explosion hazard, possible consequences of a failure of the auxiliary energy, effects of temperature and moisture, possibility of data reduction, practicability of computing operations, formation of protective and selective circuit arrangements, bridging of distances, time delay in the transmission of signals, friction and hysteresis of the various units, and the possibility of carrying out repairs on site. It is impossible to establish a clear superiority of the one or other of the two auxiliary energies. Either system has advantages differing from those of the other. The pneumatic system, e.g., is absolutely explosion-proof. The electric system, on the other hand, is free from friction and hysteresis, and the time delay in the transmission of signals is extremely small. The Teleperm-Telepneu Automatic Control System utilizes the specific advantages of both auxiliary energies.

A further progress of automatic control technology is to be expected of an increased use of automatic analyzers working in conjunction with electronic means. The combination of automatic analyzers and electronic computers permits a fully automatic process control. Viewed from this angle, electronics will gain more and more importance on the measuring side, while pneumatics will hold their ground on the positioning side of a control system.

New trend of development in the design of measuring instruments and controllers

Space-saving measuring instruments

The continuous growth and increasing complexity of chemical plants is reflected by the permanently growing number of control loops and the increasing space required for accommodating the necessary indicating and supervisory instruments in the control room. As a rule, the recording instruments require most of the available space. For many years the manufacturers have, therefore, continually aimed at equipping the control rooms with space-saving recorders and at reducing more and more the space required for accommodating the controls. In order to satisfy the demand for recording instruments of smaller size, a new version of the Kompensograph* potentiometric recorder was developed, featuring reduced front-frame dimensions. Besides meeting the requirements as to smaller measuring ranges and shorter balancing times for full-scale deflection, this new type is of universal applicability, e.g., the parts determining the measuring range can be interchanged, and the recorder is easy to handle.

Miniaturization applied to control rooms

By merely reducing the size of the instruments, however, the result aimed at is not yet attained. The switchboards and control desks, too, must be made smaller and so designed that they can be surveyed at a glance, thus contributing towards increasing the safety of operation. The new trend in the design and arrangement of small-size control rooms is a step forward towards a radical solution of the space problem, and it restores the clearness of arrangement that, owing to the continuously increasing space required by control desks of conventional design, is in danger of getting lost.

* Trade-mark

The control equipment of small-size control rooms is operated by weak current. This results in the following advantages:

1. Possibility to modify the instrumentation schedule and to carry out wiring changes without service interruption and without danger to the operating staff.
2. All control operations are performed by means of push buttons. As a matter of experience, this kind of control distinguishes itself by particular reliability and by the small space it requires.
3. The equipment provided for small-size control rooms embodies all advantages afforded by weak-current engineering, such as miniature relays, transistorized units, simple cabling, and exchangeability of the sub-assemblies for interlocking systems and selective circuits.
4. Weak-current engineering also enables safety circuits operating on the selection principle to be arranged at relatively small expense.
5. The exploitation of the possibilities of weak-current engineering in conjunction with the use of semi-conductor components has proved to be of particular advantage for the arrangement of logic circuits and for the design of process control systems.

In chemical plants, it is frequently necessary to alter the quality of the products or to change over to other products. Such plants, and consequently also their measuring and control equipment, require redesigning. This specific requirement of the chemical industry may be satisfied to a high degree by the new type of equipment for small-size control rooms, which provides that the controls and indicating instruments are centralized in the control desk. The desk itself is designed on the principle of unit construction enabling its arrangement to be easily adapted to changed conditions including switching-over to another process.

The new type of control room equipment dispenses with a continuous recording of all variables. It has proved to be quite sufficient to indicate the set points of the most important controlled variables and their deviations. Groups of other variables can be additionally selected and assigned to separately arranged recording instruments. Instead of an individual small-type recorder for each variable, an automatic data reducing equipment informs the operator only of those variables which are essential for the supervision of the process in each of its phases. By means of this automatic equipment, all important variables are continuously kept under observation for ensuring that their values remain within permissible limits.

As a result of the elimination of a great number of recording instruments, also the transducers for many variables, e.g. for all temperature and analytical values, can be dispensed with. In this case, electropneumatic controllers are preferably used.

Automatic supervision by selective systems

On the pattern of the instrumentation of nuclear reactors, multiple checking of important measuring channels by means of limit-value indicators has recently also been introduced in chemical processing plants for increasing the reliability of operation. This multiple checking is performed by a selective system. The fundamental idea underlying this system is the following: The individual units of the supervisory equipment are not immune from errors. By misleading to the assumption that the plant is out of order, an error occurring in one of the units could cause the whole plant to be put unnecessarily out of operation. Such errors are called harmless faults. It is, however, also possible that faults may develop which could prevent a real danger from being signaled. Such faults are termed dangerous faults. The selective supervisory system (e.g. a "two-of-three" system) ensures that dangerous conditions of the plant are detected and signaled. In most of these plants, an automatic shut-off system is provided which, working in conjunction with the selective supervisory system, protects the equipment in case of danger.

Automation of batch processes in chemical plants

There are still a great many of batch processes employed in the chemical industry. Whereas continuous-process control has already attained a high degree of perfection, the development of a reliable automatic control system for batch processes still remains one of to-day's problems of automation to be solved. In the case of batch processes, the individual reactions do not take place in several vessels, one after the other, but in a single container in a predetermined chronological sequence. Hence it follows that, in the case of batch processes, the flow diagram is replaced by a time schedule, and the fixed variables of the process by a time-pattern control of the physical variables of state acting on the material. Of recent years, remarkable progress has been made in the development enabling automatic control equipment to be introduced, as far as possible, for batch processes, too.

Program of control operations

In the case of chemical batch processes, first of all a detailed schedule of operations must be drawn up, stating in which sequence the individual materials should be put into the reaction vessel, how the energies are to be led in or out, and which temperatures or pressures must be applied and controlled during the process. It must further be laid down whether and when agitating should set in for mixing the components, which occurrences (e.g. formation of foam or a too rapid increase of pressure) should cause certain operations to be

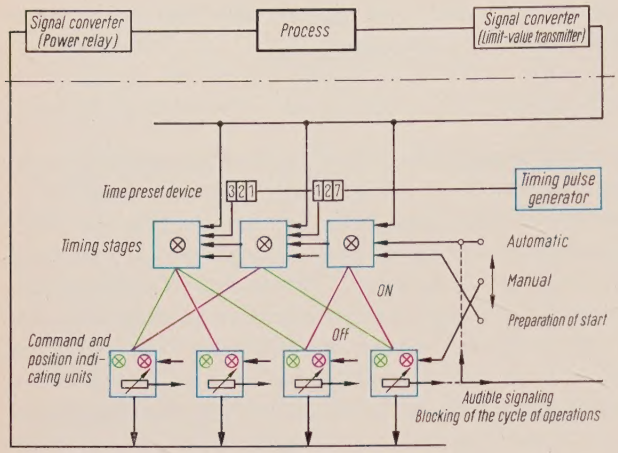

Fig. 5 Block diagram of a process control system

interrupted or modified, which time behavior should be imparted to the process variables in each phase of operation, and under which conditions the process may be regarded as completed and the reaction vessel may be emptied. Hence, an automated batch process plant contains the same measuring equipment and control loops as those provided for a continuous process plant. The control loops, however, are governed by a master control system which causes the working program, i.e. the prescription including the time program, to be realized.

Relay circuits or logic circuits are used for putting the schedule of control operations into effect. By means of a well-matched system of such logic circuits, for which the SIMATIC* System may serve as a pattern, the automation of batch processes has become possible.

It is particularly advantageous for the automatic control of batch processes if the characteristic control operations are assigned to such units which are specially designed for the purposes of timing. As a result, considerable savings in wiring, structural elements, and space are obtained as compared with the setup of pure logic systems. Fig. 5 represents a block diagram of an automatic process control system. The control equipment mainly consists of the following transistorized units: The timing stage, the command and position-indicating unit (control unit), and the timing-pulse generator. The timing stages can be excited by measured variables derived from the process, by certain time conditions, or by manual control. It is, moreover, possible to introduce secondary conditions, such as interlocking facilities.

The combined command and position-indicating units establish the connection between the timing stages and the process. The process periods are simulated by an electronic clock. Time adjusters enable periods between one second and several days to be selected.

* Trade-mark

Limit-value indicators are indispensable for all control systems. They start an alarm signal as soon as the measured variables exceed or fall below certain values. Specially adapted limit-value indicators are available for all kinds of measured variables.

Of recent years, electronics and the use of semiconductor components have given all automatic control devices their specific character. The introduction of electronic and semiconductor components enables contactless measuring and controlling circuits to be arranged in accordance with a trend of development that is gaining more and more ground in the field of instrumentation.

Supervision of processes by means of a signaling system

A contactless signaling system is available for keeping the process under supervision. Whenever a limit value is exceeded, this is indicated visibly and audibly by the fully transistorized system. The operator can acknowledge the receipt of the signal. It will frequently happen that, in the case of disturbances, the exceeding of a limit value will cause also other measured variables to deviate from their normal values. For clearing the trouble, it is important to know which limit value was the first to be exceeded. This is automatically detected by the signaling system.

Significance of miniaturization and data reduction for the automation of batch processes

Nowadays all means are available that are required for the automation of chemical batch processes. It is of prime importance that the miniaturization offers great advantages for the instrumentation of all types of discontinuous processes. Chemical batch processes, in particular, require an instrumentation of extraordinary flexibility. An installed instrumentation should readily lend itself to being adapted to new conditions.

The operator's work is further decreased by the use of data reducing equipment. These facilities are intended to draw the attention of the operating staff to those measured variables which are of importance for the existing operating conditions. They either indicate deviations from the standard condition or give information as to possible improvements of the control system.

In this connection, the telemetering and remote-control equipments may be mentioned which, being preferably designed to operate on the pulse-code method, have gained importance by their successful use in the supervision of extensive oil and gas distribution networks of the chemical industries.

Process automation by use of computers

This extensive and important field of activity cannot be treated in this paper. It may, however, be pointed out

that it would be wrong to view the problem of process automation exclusively from the angle of its solution with the aid of computers. The equipment designed for automatic process control is, first of all, expected to ensure the highest possible degree of economy, and, in the chemical industry, economy means increased output and improved quality of the product. Demands for quality, however, generally amount to demands for purity. It is, therefore, not sufficient to supply the computer merely with information concerning the operating variables. For ascertaining optimum efficiency, information as to the composition of the adjuvant substances and intermediate products is likewise required. This information is supplied by continuous-type stream analyzers. The methods of gas chromatography and infrared analysis, in particular, distinguish themselves by their excellent selectivity with respect to the accompanying components, and are, therefore, particularly suitable for working in conjunction with automatic computers. Of late years, the control engineers have concentrated their efforts upon the development of automatic control systems. In the years to come, however, they will direct their attention more and more to the process itself and, in particular, to the development of efficient analyzers which are the key to optimum process control.

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Progress in Power Engineering as applied to the Chemical Industry

By Gustav Funk

The Siemens-Schuckertwerke have always been very interested in the question of power supplies for the chemical industry and have devoted special attention to this subject. The work of devising the best methods has been carried out not only in the design and construction offices or in the workshops and test departments of the factories but also in the laboratories and special development, planning and application engineering departments at headquarters [1].

Power supply

Different methods of generating electrical power have been followed, depending on the energy sources and production programmes. In Western Germany since 1945 the tendency has been to restrict local generation to the utilization of the heating steam in back-pressure turbines, of course in the most economical way, by far the greater part of the rest of the electrical energy being drawn from the public supply system. This state of affairs in the chemical industry provided the inducement for the development of the high-temperature turbine with 600 to 650 °C steam inlet temperature at pressures of 180 to 300 kg/cm² gauge (2,560 to 4,270 psig). The first turbine of this kind went into service in 1952. Since then nine machines have been installed or put in hand by the Siemens-Schuckertwerke alone (Table 1 and Fig. 1).

Number	Rating MW	Pressure* kg/cm² gauge	Inlet steam temperature °C	Back-pressure* kg/cm² gauge
1	11.4	160	625	31
3	14.0	180	650	31
1	16.5	325	620	118
1	28.5	185	615	19
2	21.0	180	650	6
1	17.8	230	560	65

* 1 kg/cm² = 14.22 psi

Table 1 Siemens high-temperature turbines in the chemical industry

For conventional steam turbines in the medium and lower power range, as are required for service in fertilizer factories [2], the Siemens-Schuckertwerke built a special steam-turbine factory in Wesel some years ago.

The advances in automatic regulating equipment for steam power stations e.g. the back-pressure regulating system with the Teleperm* Z automatic controller are

* Trade-mark

utilized, as are also those of relay circuits, e.g. electrical automatic transfer devices, which, on the occurrence of disturbances, ensure supply to essential loads.

In other countries, however, the conditions are often quite different. When new chemical works are erected in areas where there is no interconnected system of adequate load capacity, it is necessary to build local power stations with condensing or extraction-condensing turbines; in such power stations generating sets of 60 to 70 MW are by no means rare. For a chemical works power station in Southern Europe for example two turbo-generator sets each of 64 MW are in hand. For the electro-metallurgical industry, as in colliery power stations, sizes of generating sets have already reached 150 MW.

In the case of distribution systems the increase in magnitude and density of load necessitates the adoption of higher voltages. The numerous chemical works built before 1939 included high-voltage distribution systems of 5 or 6 kV. Even at that time, however, this kind of system was only to be recommended when the main power-consuming plant, e.g. large compressors, electrolytic plant or furnaces, were located close to the power station.

Nowadays the load concentration in extensive works of the chemical industry necessitates the superposition of systems of higher voltage such as 25, 30 or 110 kV, into which the power is fed from generators of the local power stations through transformers or from the public supply undertakings. There are already a number of such 25 and 30-kV systems with short-circuit capacities up to 1,500 MVA. The 110-kV points of infeed take the form of indoor substations, fed through cables, also located within the factory premises. Large works with power transfers of several hundred MVA are nowadays also connected to the 220-kV system.

Centralized remote control and supervision of large power systems can only be carried out conveniently in control rooms with selective control systems (Fig. 2) or by the latest and best method with mimic diagram control [3] using contactless logic elements (Simatic*).

The heavy high-voltage main switchgear of the insulation ratings 10 and 30 kV with circuit breakers with rated breaking capacities of 600 to 1,500 MVA is, as before, of the open indoor type, as in any case it has generally to be accommodated in closed switch houses.

Sheet-steel-enclosed, high-voltage, cubicle-type switchgear with breaking capacities of 100, 250 and 400 MVA has been widely used in the chemical industry for sub-distribution boards (Fig. 3). It is practically indispensable for export orders, when complete electrical equipments for new chemical works overseas have to be supplied, e.g. in the countries of Asia and Africa now in the course of development; account has then to be taken of the special conditions in the country (humidity, vermin, etc).

Combinations of high and low-voltage, sheet-steel-enclosed switchgear with flanged-on Clophen-filled transformers, so-called load-centre unit substations, which could be installed at centres of load, represented a notable advance [2].

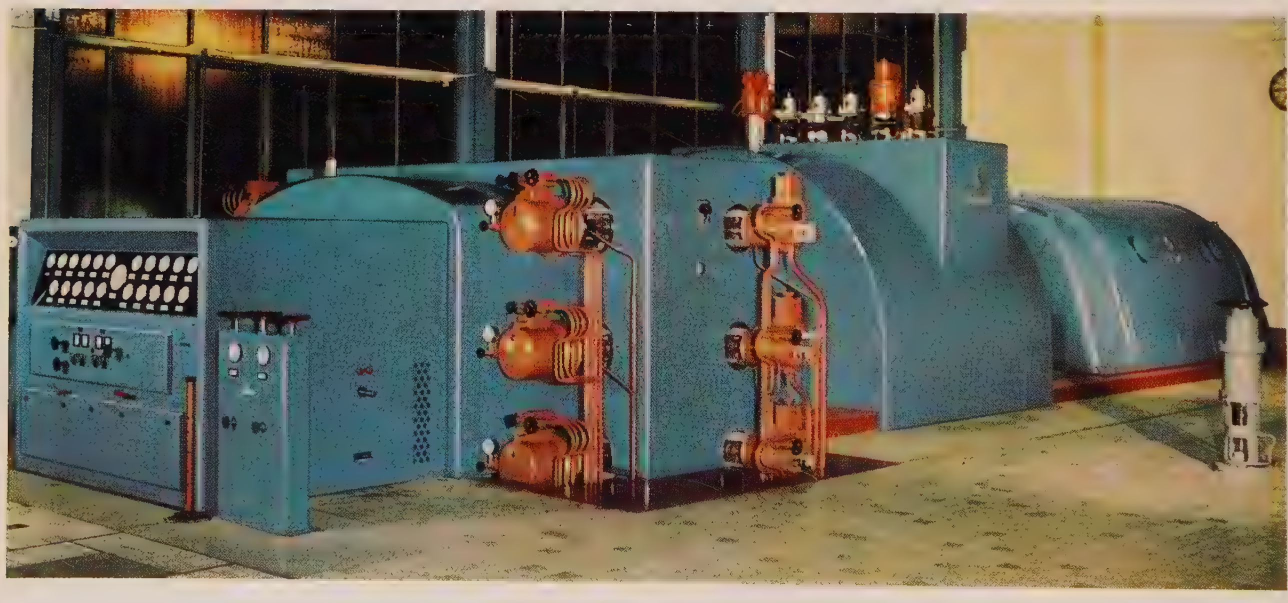

Fig. 1 Extraction/back-pressure turbo-generator set, 21 MW, inlet steam 150/180 kg/cm² gauge, 640/650 °C, controlled extraction at 16 kg/cm² gauge, back-pressure 6 kg/cm² gauge (1 kg/cm² = 14.22 psi)

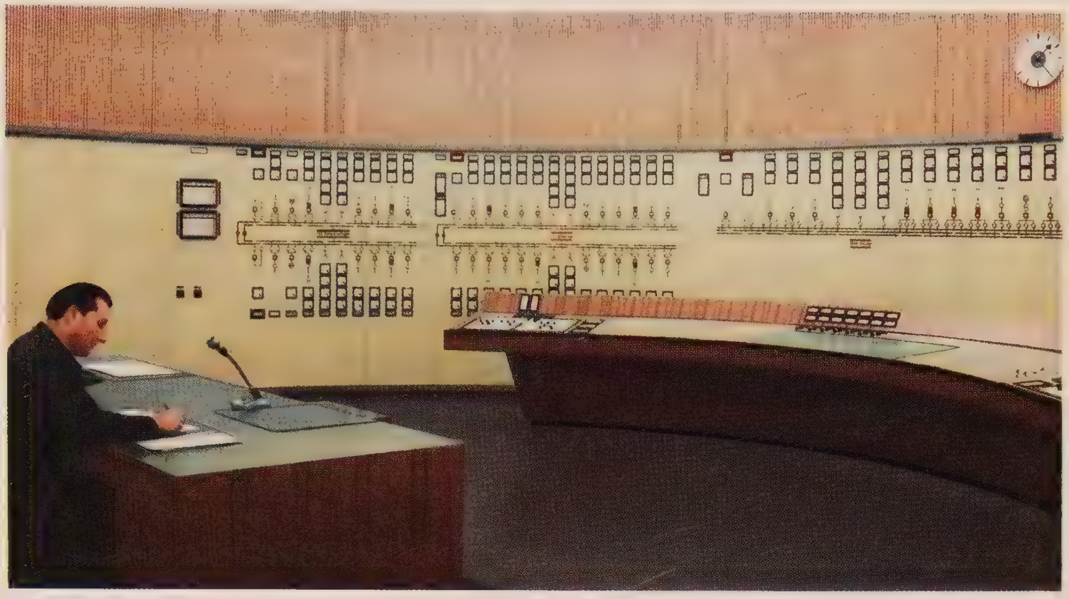

Fig. 2 Electrical control room with selective control system in a power station of the chemical industry

In the case of sub-distribution boards for low voltage the increasing use of control gear for electrical drives necessitated the development of a larger sheet-steel-enclosed combination system (EN-system), in which in addition to busbars, fuses and protective switches also contactors, relays and automatic controllers for the controls are accommodated (Fig. 4).

Silicon rectifiers for electrolytic plants

The most radical change in the power supply equipment of chemical works has probably been due to the development and introduction of the silicon rectifier for d.c. supplies to electrolytic plant of all kinds. In June 1957 the first Siemens silicon rectifier was connected to a chlorine-producing electrolytic plant. Since then the Siemens-Schuckertwerke have received orders for 70 installations with a total output of more than 2.2 million A, of which 45 are already in service. They have proved entirely satisfactory; the oldest have now been in operation for more than three years and supply electrolytic plants at voltages of 50 to 1,000 V. These include large electrolytic plants for aluminium and chlorine with currents of 82,000 and 100,000 A, respectively [4, 5].

With silicon rectifiers the voltage control gear involves higher cost, as not only regulating transformers for coarse control but also special transductors for fine control are necessary. Rectifier transformers of special design incorporating transductors of the single-conductor type have been developed. In combination with a two-step transistor controller and magnetic amplifier they make possible a constant-current control system with high speed of response and high accuracy, which has been used in nearly all electrolytic plants with silicon rectifiers and has proved highly satisfactory. A further notable development is the automatic current-programme control used for forming lead-acid batteries. In this case a current/time programme is required, which is different for every type of plate. The programme is prescribed by means of punched cards or plug-in programmes and then proceeds automatically. In an installation of this kind an unregulated voltage of about 80 V is produced by a 3,800-A base-load silicon rectifier; superimposed on this is a supplementary voltage up to a maximum of 40 V supplied

Fig. 3 Sheet-steel-enclosed, high-voltage switchboard with double busbars, 200 MVA, 6 kV, in a chemical works in India

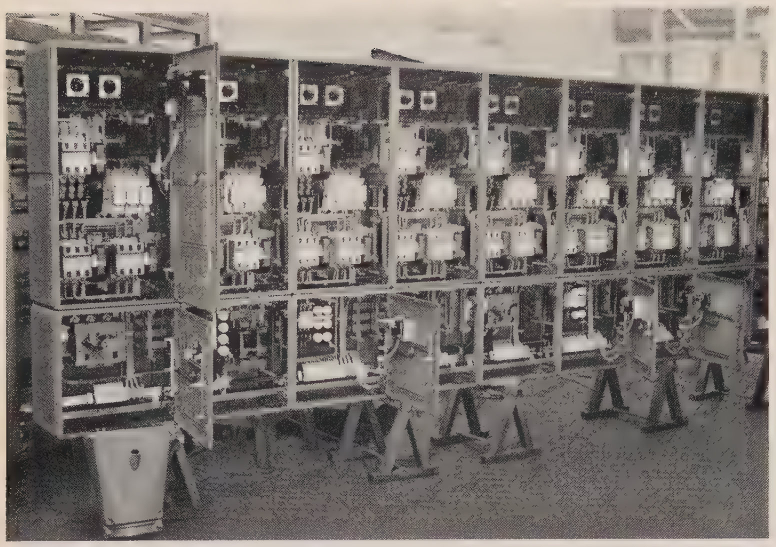

Fig. 4 Control gear for nine centrifuge drives in a large chemical works enclosed in EN-system housings

made of seven three-phase sets each rated at 60 MVA with a secondary current of 120 kA [6] and a single-phase bank with a total output of 70 MVA and a secondary current of 75.3 kA. The decision between three-phase and single-phase sets is a matter for the users; the supplier can meet their wishes in all respects. As the transformers are placed immediately adjacent to the furnaces the 110-kV supply must be brought in by cables. The sealing boxes for oil-filled cable [6] on a 110-kV three-phase transformer can also be exchanged for porcelain terminal bushings for connection to an overhead line. Built-in 110-kV toroidal current transformers enable the primary current to be measured. The construction of larger 110-kV units or the direct connection to a 220-kV system are quite practicable. Limits are set only by transport considerations.

by smaller 200-A supplementary rectifiers. By varying the supplementary voltage the current is automatically held constant according to the set programme by means of transductors and a transistor two-step controller.

The manufacture of Hall generators of high output based on $A_{III}–B_V$ compounds some time ago made possible the practical application of the Hall effect for accurate measurement of heavy direct currents in electrolytic plants. A further condition for accuracy of measurement is, however, a control current which remains constant to within 0.01%. The new transistorized equipments now fulfil this requirement also. The high-current yokes provided to accommodate the Hall generators can at present be supplied up to 150 kA; for higher currents summation measurement is recommended.

Furnace transformers for reduction furnaces

In 1957, the Süddeutsche Kalkstickstoffwerke, Trostberg, put into service furnace transformers for direct connection to the 110-kV system. These comprised four single-phase units, including one spare unit, each of 14.6 MVA with a secondary current of 60.8 kA. In these an economical form of construction, which had been recommended by the Siemens-Schuckertwerke for many years, was put into practice for the first time. This form of construction offers advantages in efficiency and capital cost. When transformers of the older type with a high-side voltage of 10 to 30 kV were supplied from the 110-kV system separate coupling transformers of, for example, 110/10 kV with corresponding switchgear were required.

Because of the excellent results obtained in the plant mentioned above the decision was made in other quarters also to install similar transformers for large carbide and phosphorus furnaces. Mention may be

Electrical electrode-control systems have been further improved by the development of a three-step controller with minimum frequency of switching. This equipment assesses the deviation not according to its instantaneous value but according to magnitude and time integral, thus restricting the number of control actions to a minimum. A high average accuracy is thus attained.

Electrical drives

Squirrel-cage induction motors are still the most important drives in the chemical industry. Although the totally-enclosed, fin-cooled induction motors made by the Siemens-Schuckertwerke for over 35 years have been further developed, e.g. for use in explosive gas atmospheres in the type of protection "Increased Safety" (Ex)e or "Flameproof Enclosure" (Ex)d the basic idea has remained unchanged.

An important step was the standardisation of mounting dimensions in accordance with IEC Recommendations 72–1 and the correlation of output ratings of surface-cooled, low-voltage, squirrel-cage motors for use in explosive gas atmospheres according to DIN 42673 in 1960 [7]. Improved air flow, a better arrangement of the cooling fins and the consequent increase in the effective cooling surface have enabled the type rating of these motors to be considerably increased. Fin-cooled, high-voltage motors are now supplied in cast-iron frames up to 300 kW and flameproof motors with welded housing up to 500 kW, in each case 4-pole [8].

For large motors for turbo-compressors and reciprocating compressors there has been an increasing tendency towards total enclosure, the air coolers being built into the stator frame (Fig. 5). The external appearance of the motors has thus been completely

changed. The advantages of this arrangement are particularly evident during erection. Since 1945 the Siemens-Schuckertwerke have supplied large motors with an aggregate output of 500,000 kW to the chemical industry; synchronous motors, which with induction motors still maintain their position, account for about 40% of the total rating. The development of large motors, problems of insulation and noise reduction etc. have been dealt with separately elsewhere [9].

Recently, considerations relating to certain processes in the chemical industry have necessitated increased application of variable-speed drives. In the past a.c. commutator motors have occasionally been used when a certain range of speed was required. With the erection and extension of production plants for the manufacture of the plastic materials poly-ethylene and polypropylene automatically controlled d.c. drives were first employed to a considerable extent. The most favourable methods of adjusting the speed are by varying the armature voltage by means of voltage-controlling transductors, mercury-arc rectifiers or Ward-Leonard control sets. Additional control functions, e.g. regulation of pressure or flow by speed variation, can be effected by means of the numerous recent developments in automatic control.

For powers up to about 250 kW, as are used for stirring machines and screw extruders, the d. c. motor fed through transductors has technical and economic advantages. For higher powers, e.g. for reciprocating compressors, the grid-controlled, mercury-arc rectifier is more suitable. Well-proven rectifier tanks, single or multi-anode, with transistor grid-control units are available for all powers required [10].

The transistorized controllers employed are built up of transistor amplifiers, which have negligible inertia; they are easily adjusted and have a very short response time. By dividing up the control system into a number of secondary loops, the desired values of which are prescribed by the master controller, adaptation to the most severe requirements is possible. For the application of transistorized controllers to practical chemical processes advantage was taken of years of experience with large rolling-mill and hoisting motors [11 to 14].

By the use of the silicon rectifier the long familiar sub-synchronous induction set has been made into a high-grade, low-loss variable-speed drive for speed reduction down to about 70 % of synchronous speed. Such drives are specially suitable for turbo-compressors. The slipring power of the main induction motor is converted by means of a silicon rectifier in a three-phase bridge connection into direct current and is then fed back to the system, either through a rotary convertor or an inverter or, in the case of high-speed drives, it is converted into mechanical power through a d.c. machine coupled to the main induction motor. For drives working in explosive atmospheres feedback into the supply system is preferred, as the necessary equipment can be installed away from the motor in a room not exposed to explosion hazard.

New possibilities at present employed only for fairly small powers result from the supply to d.c. motors through controlled multi-layer rectifiers on a silicon basis.

Control gear for drives

The advance of automation in the chemical industry has caused a great increase of interest in control gear for drives. A wide variety of suitable signal transmitters and controllers is now available. The technique of the control of transport and mixing of the raw materials, intermediate and final products is of increasing importance. To ensure the smooth flow of material within an extensive production and transport section the use of centralized control systems with luminous flow boards is recommended (Fig. 6). Extensive switching operations proceed automatically, faulty switching is avoided and the operating condition of the plant can easily be seen at any time. Control gear in chemical works must be enclosed and located with due regard to possible danger of corrosion or explosion. The metal-clad EN-distribution boards have already been mentioned. For very extensive control

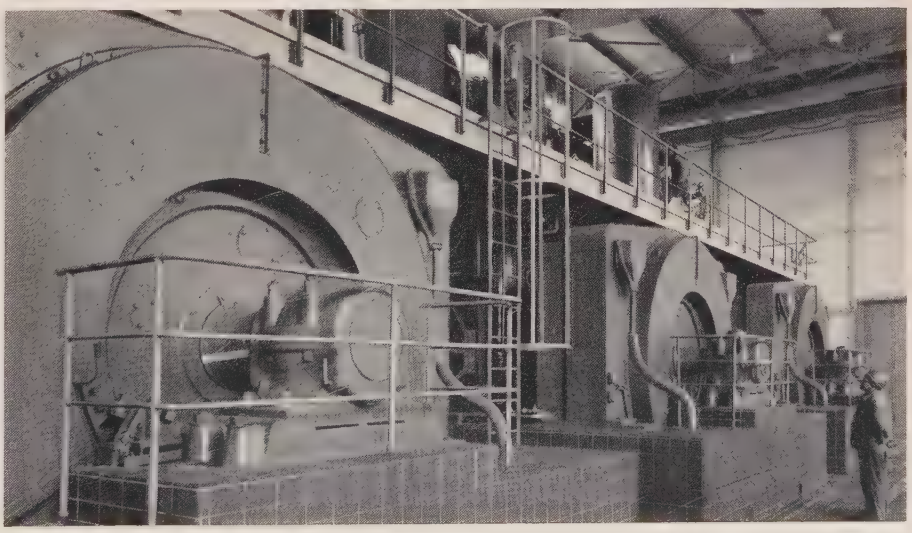

Fig. 5 Compressor motors, 1,300 kW, 6 kV, 245 r.p.m., with built-in coolers

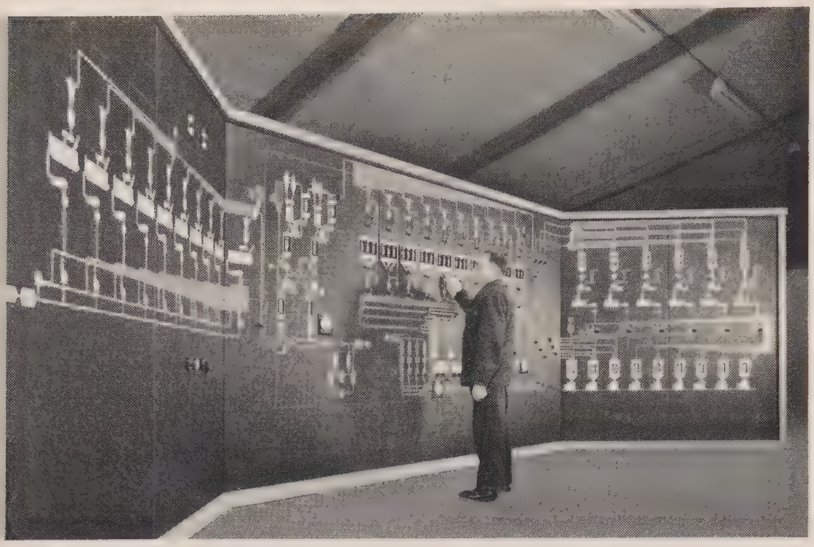

Fig. 6 Luminous flow board for a plastics works

systems and in factories subject to explosion hazard the control gear must be installed in special electrical operating rooms not subject to such hazard, unless it is unavoidable that the control boards be installed in hazardous locations, in which case the extra expense for flameproof enclosure must be borne.

New opportunities for building up control systems are presented by the use of logic elements such as those of the Simatic system. They are always advantageous whenever very rapid occurrences are concerned, e.g. high-speed counting, which is beyond the scope of normal contact-making devices or when the absence of contacts is of decisive importance. A start has already been made with the introduction of the Simatic system in controls in the chemical industry, e.g. in the automatic starting equipment for large synchronous motors. In this case the frequency of the alternating current induced in the field circuit is digitally measured and is converted into a command signal. Using Simatic components and Hall pulse transmitters a digital angle-measuring equipment for reciprocating compressors driven by synchronous motors has also been developed. This also enables a motor to be run up to a prescribed angular position. The advantage as compared with methods previously employed is not only the absence of contacts or sliprings but also the possibility of detecting the crank angles of a number of compressors simultaneously.

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Destination Factor and Traffic Flow Measuring Equipment for Dial Offices and Networks

By Karl-Wilhelm Schönberger

For obtaining the parameters required in the planning and operation of dial offices and PABX's, the volume of traffic can be measured at a single point or the flow of traffic can be observed over long routes [1, 2, 3]. The traffic flowing through a respective switching stage is registered by traffic measuring equipment (VME) [4], and classified according to call destinations by destination factor and traffic flow measuring equipment (ZME) [5, 6]. This classification of traffic – which is possible with the aid of the information dialed by telephone users – acquires particular importance in the large networks used in direct distance dialing.

The results of destination factor and traffic flow measurements permit the objective appraisal of the occupancy of local and long-distance dialing networks, and furnish

information as to whether new inter-office paths should be installed or existing ones adapted to the changed traffic conditions [7]. The number of successful calls, attempted calls and busy conditions per line connector group and per line unit can also be registered [8], and the influence of calling and called parties on the flow of traffic determined [9]. Such measurements furnish design center data that could hitherto only be obtained by means of troublesome methods and sometimes only by estimates.

Parameters of traffic flow

Destination factor and traffic flow measuring equipment furnishes two classes of data: one represents the influence of telephone users on the flow of traffic; the other shows the effect of the equipment of dial offices.

The calls made, say, by the subscribers of dial office A to subscribers of dial offices B, C and D represent what is termed the call distribution; the respective sums of the holding times represent the traffic volume distribution. The destination factor Z_{Y_x} referred to the traffic volume, is defined as the ratio of the observed traffic volume Y_x, with the observed route x as its destination, to the total traffic volume Y_{tot} registered by the measuring equipment in random sampling the traffic of all routes.

Hence

$$Z_{Y_x} = \frac{Y_x}{Y_{tot}}.$$

As the traffic volume represents the product of the calls processed during an observation period multiplied by the average holding time, the destination factor is also represented by

$$Z_{Y_x} = \frac{C_{A_x} \cdot t_{m_x}}{C_{A_{tot}} \cdot t_{m_{tot}}}.$$

C_{A_x} denotes the number of calls offered to route x during the observation period; t_{m_x} denotes their average holding time; $C_{A_{tot}}$ denotes the number of all the offered calls registered by the measuring equipment; $t_{m_{tot}}$ denotes their average holding time.

If $t_{m_x} = t_{m_{tot}}$, then

$$Z_{Y_x} = \frac{C_{A_x}}{C_{A_{tot}}} = Z_x\,(C_A)$$

The destination factor Z_{Y_x} referred to the traffic volume and assuming the same average holding times is equal to the destination factor Z_x (C_A) referred to the number of offered calls.

The telephone user not only determines the destination of his call but also influences the length of the dialing delay. The time from the beginning of dial tone until the telephone user dials the first digit is termed the dial-tone listening time. The time between the end of one train of dial pulses and the next is termed the interdigit pause. Instances where the interdigit pause exceeds, say, 10 sec (zoner is automatically disconnected) count as timed lockouts. The time from the beginning of busy tone until the telephone user replaces his handset is termed the busy-tone listening time. Finally, the number of abandoned calls represents the number of times that telephone users give up trying to make a call.

Apart from these time intervals that are dependent on the calling party, there are others that depend on the called party. The answering delay is the time from the

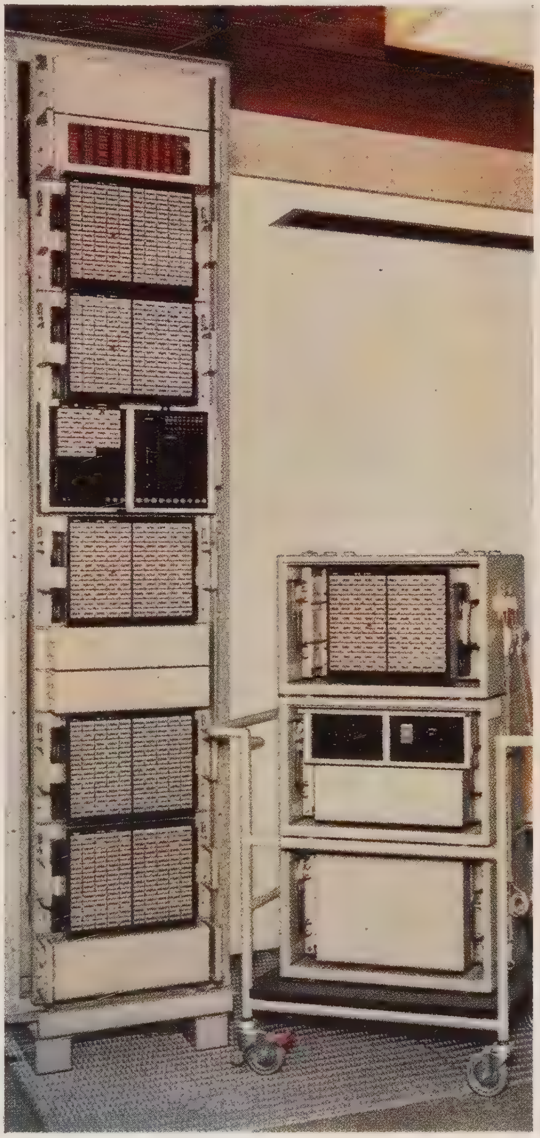

Fig. 1 Destination factor and traffic flow measuring equipment. Left: installed in measuring frame. Right: in standard cases placed on trolley

splash ring until the called party answers: answers represent the number of times that called parties answer calls. Other factors of interest are the no-answers, i.e. the number of times that called parties do not answer within a set period, and the number of called-party-busy instances.

The second class of data registered by the destination factor and traffic flow measuring equipment is not influenced by telephone users and furnishes information on the equipment of the dial office. This body of data covers all-lanes-busy conditions, delays and exceeded delays encountered during the establishment of calls owing to the peculiarities of the dial system and, in systems with alternate routing, the number of calls that flow along direct paths or along the final path. The number of calls offered to a route, the number of calls carried by the route, and the number of calls lost should stand in a certain ratio to each other. This ratio furnishes information with respect to the grade-of-service of the dial office.

In addition to the foregoing measurements, it is recommendable to check at regular intervals the number and duration of successful calls and the times of day at which they take place. Such traffic will depend in part on tariff regulations and on the structure of telephone users: the use of a graduated tariff may lead to the flattening of traffic peaks, while changes in working hours and places of residence may completely transform traffic conditions.

An analysis of the numerous parameters that can be determined by destination factor and traffic flow measuring equipment will be published at a later date.

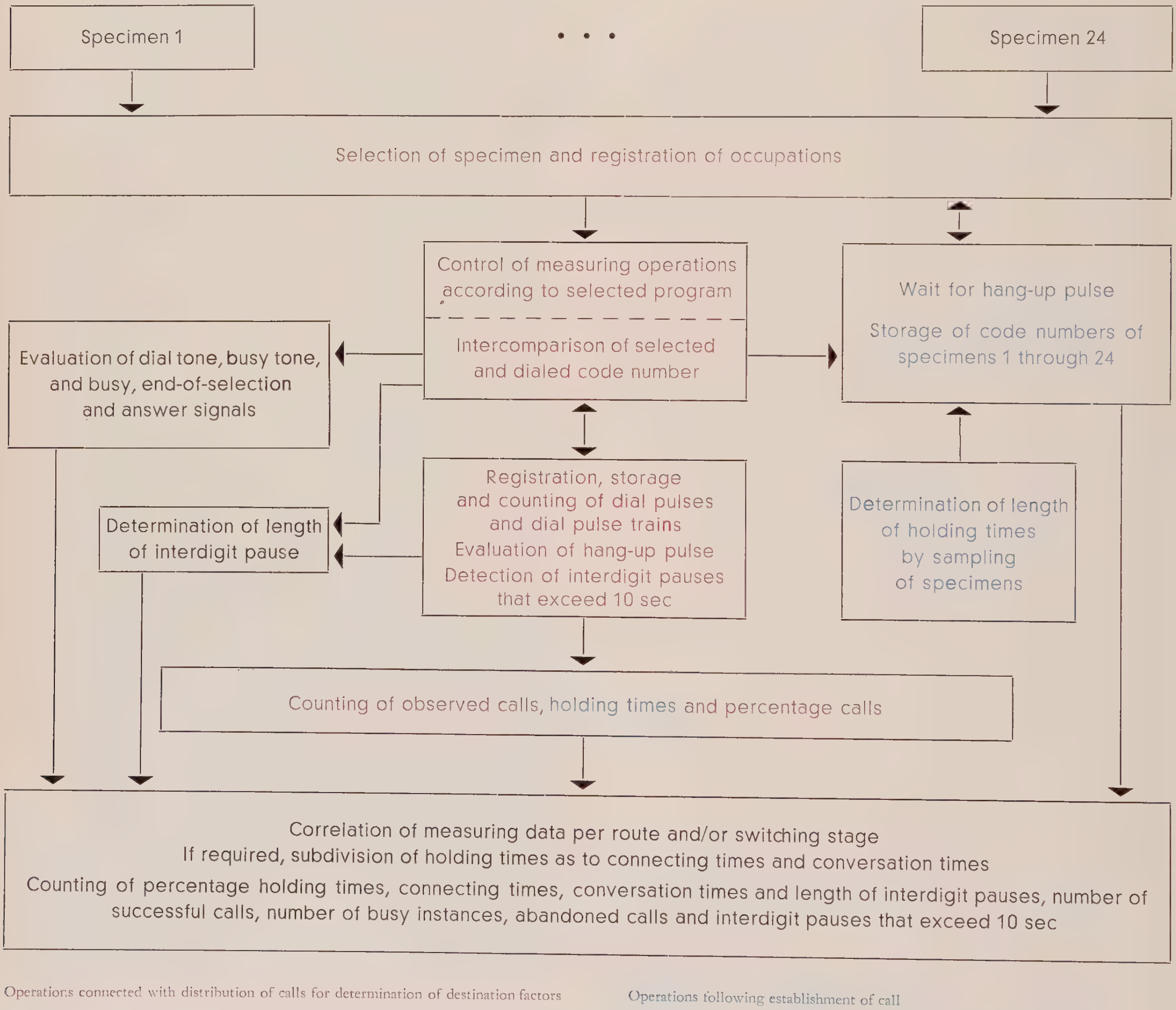

Fig. 2 Use of destination factor and traffic flow measuring equipment for determining all parameters

Measuring equipment

The destination factor and traffic flow measuring equipment (ZME) is composed of various basic units that are assembled with the aid of plug-terminated connecting cords. The following units are available: an input distributor allowing connection of other units; a connecting adapter for registration and evaluation of calls; a destination factor relay set for storage and evaluation of dial pulses and system codes; a code evaluator; a busy-tone/dial-tone evaluator; an interdigit-pause attachment for determining the length of interdigit pauses and the length of conversations; a control unit for selecting the desired measurement, type of registration, and adaptation to the respective system code; a large indication and control panel for indicating and checking the selected measurement and the extent of random sampling; and several meter panels for indicating and summing the registered data. Measurements can also be made successively by using the same units of equipment over and over again.

Fig. 3 Measuring equipment for determination of destination factors. Seen in the background is an example of the graphical representation of a measuring result

The equipment can either be installed permanently in frames or used in portable cases (Fig. 1). In its portable form it can be used for the periodical checking of various dial offices or large PABX's.

The equipment is connected to 1 through 24 specimens (switches or trunks) and successively registers the number of times they are used (see Fig. 2). Whereas the extension of calls is observed on a one-at-a-time basis, the measuring equipment determines the holding time and conversation time for all lines simultaneously. If the equipment is permanently installed, the access points at the dial office or PABX are assigned respective input distributors with three patching panels in the associated intermediate distribution frame. For portable applications the equipment is connected to the specimens at an input distributor with jack panel. Plug-terminated cords run from the input distributor to the test jacks of the switching devices [5]. If destination factors are to be determined primarily only for one specimen, all that is required is a destination factor relay set and a small indication and control panel (Figs. 3, 4). This furnishes meter readings of the call destinations as percentages of the overall traffic, the number of unsuccessful calls, and the number of interdigit pauses that exceed 10 sec. Measurements are performed on a single device such as a switch, zoner or storage. The provision of access to the zoner or storage of a junction office or sectional office secures the advantage of faster measuring, for central devices such as storages and zoners have shorter holding times and

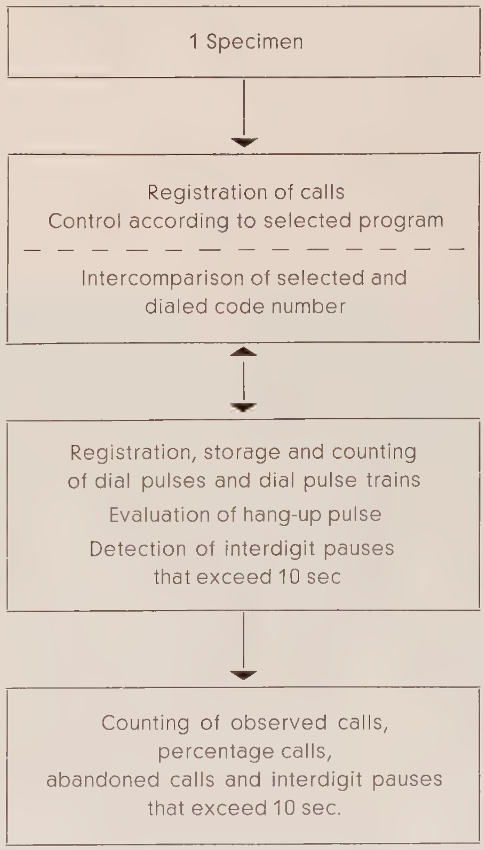

Fig. 4 Use of measuring equipment for determination of destination factors

therefore experience more frequent usage within a given observation period.

The accuracy of the destination factor and traffic flow measurements depends on the extent of random sampling (confidence interval) [10], which may be read on meters as the sum of all the observed calls and holding times.

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The Illumination of High-level Roads and Tunnels*

By Gerhard Smiatek

Road building is at present undergoing a striking transformation: Town planners and road builders are faced with the task of mastering the increasing traffic density on the roads and are consequently compelled to construct urban motorways and trunk roads in the form of high-level roads, low-level roads and tunnels. These roads, which are designed on generous lines hitherto almost unknown, not only make high demands on the ingenuity of the road builder but also confront the lighting engineer with problems of a very difficult nature.

* Taken from lectures held by the author at the Meeting of the Norwegian Selskapet for Lyskultur on Feb. 22, 1961 in Oslo and at the Meeting of the Danish Lysteknisk Selskab on Feb. 25 1961 in Copenhagen.

Parapet-mounted luminaires on high-level roads and bridges

High-level roads are trunk road sections elevated about 5 to 8 m above the level of the other roads over considerable distances. Conventional street lighting is not always suitable for these new roads since the architec-

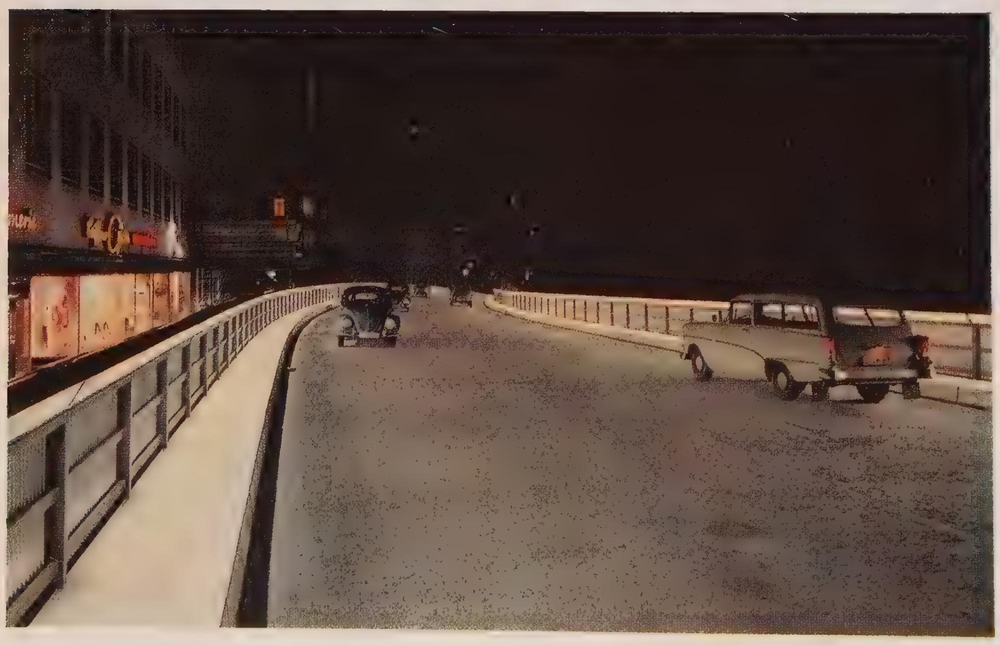


Fig. 1 High-level road with parapet-mounted luminaires

tural design would be spoilt by span wires and lighting columns.

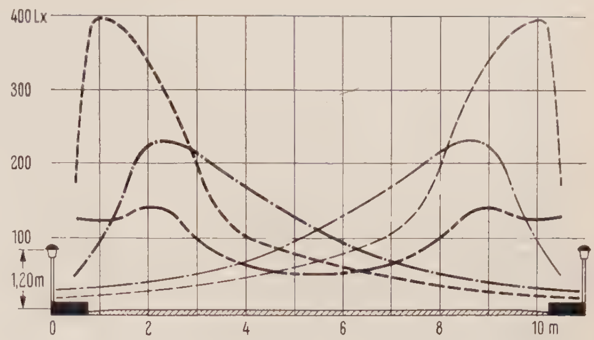
Since safety regulations require that high-level roads be provided with parapets even when there are no pedestrian walkways it would seem practical to install the luminaires in the handrail of these parapets (Fig. 1). In this way the luminaires are practically concealed during the day and form a harmonious entity with the parapet. Continuous lines of such luminaires, on one or both sides of the road, meet all the requirements of good street lighting [1]:

a) The illumination level on the carriageway is high. For a light-coloured, dry road surface (concrete) a mean luminance of about 3 to 10 cd/m^2 is obtained, applying the conventional methods of calculation. However, this value can only be taken for guidance purposes. In actual practice it can be very different, the luminance being namely higher in many cases as a result of the reflection characteristics of road surfaces depending on the angle of incidence. The luminance of 2 cd/m^2 recommended by de Boer [2] for satisfactory seeing conditions is not only reached but is far exceeded. Then there is the fact that, in addition to the high horizontal illumination, the vertical component also assumes very high values (Fig. 2).

b) Wide roads require specular-reflector luminaires. The light is adequately concentrated by reflector-layer fluorescent lamps. In conjunction with the specular reflector, the increased lamp luminance guarantees the desired light distribution.

   The specular reflectors are adjusted to keep the luminous flux below the horizontal (Fig. 3). The eyes of the driver are then always in the dark zone of the light distribution and he is therefore not dazzled (Fig. 4). Black cross louvers can be used to prevent the direct view into the lighting strip and thus reduce the danger of high luminances on specular surfaces. The normally desirable light distribution according to Lambert's Law in the longitudinal axis of the luminaire is thus flattened. When calculating the illumination level then, the continuous-line formula must be modified, as shown by Roch [3] for a continuous line with flattened light distribution. In the example selected the correction factor is 0.5. For the luminance on the road surface a light distribution according to Lambert's Law would then be better. Instead of the louvers, therefore, other structural measures have to be taken to prevent glare from the luminaire.

c) Large vehicles with overhanging loads constitute a particular danger in darkness, both for the vehicles behind and for those approaching from the front. In the parapet luminaires specular reflectors of special design are used to illuminate such loads or the top parts of trucks adequately (see Fig. 4). The bottom part of the channel reflector is angled and reflects a portion of the light into the space above the horizontal. The dark zone located between the two main directions of light emission is governed by the design of the specular reflector and can be adapted to the conditions prevailing. If, for instance, the entire road is sufficiently illuminated by light-coloured façades and shop windows, even above the horizontal line of sight of the driver, it is not necessary to direct a portion of the light upwards. The entire luminous flux is then used to illuminate the carriageway and the efficiency of the installation is thus increased.



—·— E_H on a level with carriageway
=== E_V 55 cm over carriageway
=·= E_V on a level with carriageway

Fig. 2 Example showing the horizontal and vertical illumination E with parapet luminaires

d) Parapet luminaires are also an excellent guide for the driver, no matter whether they are on only one or on both sides of the road. Particularly in fog, this type of lighting is superior to all other systems. The run of the road can be made out from great distances. With diffuse reflecting road surfaces a uniform luminance distribution is obtained.

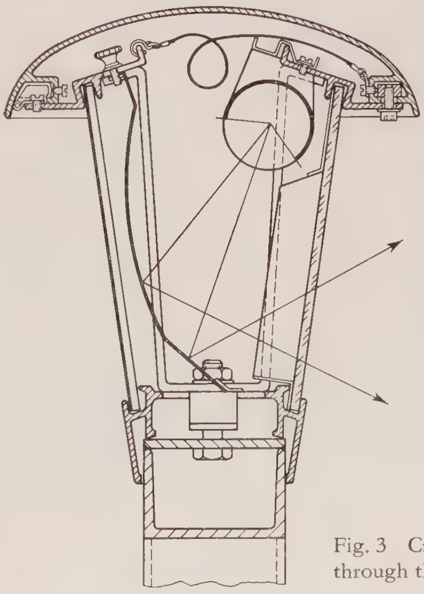


Fig. 3 Cross section through the parapet luminaire

e) It would be wrong to abandon the system of continuous lines. As illustrated by R. Janzen [4] in model experiments, flashing effects in the peripheral field of vision of the driver are particularly disturbing. This is at a maximum when the flashing frequency is about 8.5 c/s, i.e. when the vehicle passes 8.5 light sources in 1 sec. This makes it possible to calculate the lamp spacings which would give rise to particular discomfort at the various speeds. Since vehicles are driven at all manner of speeds on high-level roads, a continuous line of luminaires is imperative, not to mention the other advantages referred to in connection with such a system. Should the illumination level obtained be too high, the power input and illumination can be reduced by at least 50% by means of a special circuit arrangement of the reflector-layer fluorescent lamps.

f) Parapet luminaires are more expensive than conventional units. This is balanced, however, by the fact that much better illumination is achieved which, in turn, increases road safety. If one considers, however, that the columns and span wires otherwise required and not at all conducive to architectural harmony can be done away with and that the parapets are in any case necessary for reasons of safety and can readily be used for mounting the luminaires, the real difference in the initial costs is no longer so great. Installation and maintenance can be carried out without hindering traffic and without having to employ cumbersome maintenance cars with their telescoping platforms and ladders. Owing to the higher installed lamp wattage, the electricity costs and lamp replacements may well be higher than with other types of lighting installations but it must not be forgotten that lighting which helps to prevent accidents is always a saving for the State. It is better to spend money on the prevention of accidents than on the damage resulting from such.

There are also examples in other fields of the great advantages of such lighting installations with the luminaires mounted in the handrails. Glare-free lighting of bridges etc. is required, on waterways and railways. Parapet-mounted luminaires also render good service in the approaches and turn-offs of motorways and trunk roads by providing the drivers with a clear optical guide in these danger spots. Of course, such lighting can only be used when the sections preceding the approaches or turn-offs – with a falling or rising gradient – are also lighted in order not to dazzle the driver as he comes out of the darkness and to help the driver emerging from the light into the darkness to adapt himself to the changed conditions [5].

Lighting of tunnels

Towns and cities do not always have room for the construction of high-level roads. The town planner often finds a solution to this problem in building low-level roads or in constructing tunnels to take the roads under whole sections of the town. In mountainous regions it is often easier to tunnel under the rock than to take the road over the mountains.

The lighting of tunnels by day presents a particularly difficult problem [6 to 9]. The illumination level in the tunnel is governed by the level of the natural daylight outside and from the speed of the vehicles.

The human eye is capable of adapting itself within very wide limits to the surrounding brightness. However, this process takes place not without a certain amount of inertia. Approximately one minute is required for the pupil to respond and increase in cross section, for the eye to adapt itself to the darkness and for the sensitivity to increase to about a hundred-fold. The driver approaching an unlighted tunnel in broad daylight sees the latter merely as a black hole. After entering the tunnel, even with his headlights on, he has the impression of being enshrouded in darkness for some considerable time. Such a situation is naturally highly dangerous. If the speed limit on the approaches to tunnels has therefore to be done away with in order not to slow down and hinder the flow of traffic, the luminance at the tunnel entrance and for a sufficiently long stretch inside the tunnel must be such that the transition from daylight to the light inside the tunnel is possible without seeing conditions being impaired (Fig. 5).

The best solution is to match the illumination in the tunnel as near as possible with daylight or at least to make it high enough to enable the eye to

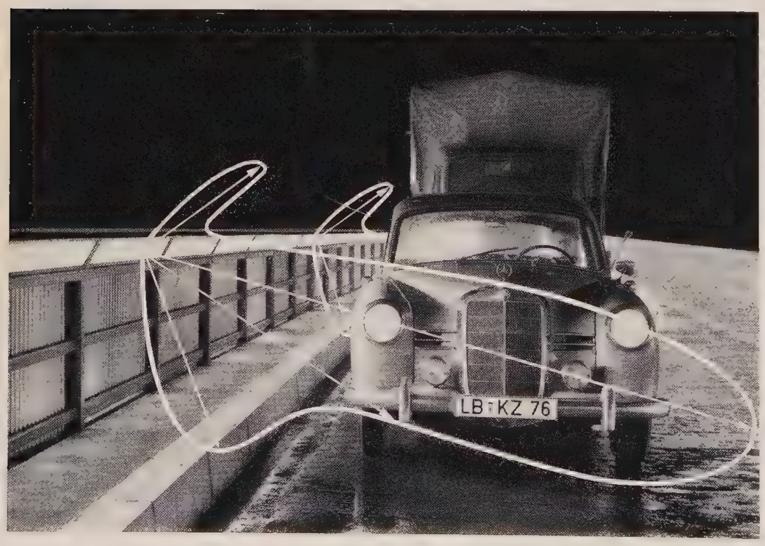


Fig. 4 Parapet luminaires and light distribution on a high-level road in Stuttgart

cope with the difference in brightness without too much difficulty. Short underpasses can generally not be lighted in any other way since the driver has not sufficient time to adapt himself to changed conditions – at a speed of 63 m.p.h. 153 yards are covered in 5 seconds! However, such daylight lighting would be far too expensive for long tunnels.

Fig. 5 Lighting in an underpass by day in Augsburg

A compromise must be based on the physiological behaviour of the human eye. When a car enters a tunnel, the eye of the driver is subjected to the influences of two different phenomena: indirect glare, which substantially reduces contrast sensitivity, and the natural adaptation of the eye which tries to bridge the differences in luminance outside and inside.

If, for instance, the illumination level in the tunnel is 50 lux and that in front of the tunnel 50,000 lux during the daytime, the ratio between the luminances inside and outside is therefore 1 : 1,000, assuming that the reflection factors are the same. Under the most favourable conditions, however, the maximum contrast sensitivity, expressed by the relative luminance difference threshold, is at the best 1 : 100, i.e. a 1% difference in luminance can still be perceived. In vehicular traffic, however, less contrast sensitivity must be expected, as illustrated in the following example:

A car driver approaches a tunnel in daylight at a speed of 63 m.p.h. From the moment an obstruction is recognized until the car comes to a standstill about 165 yards are covered, assuming a dry road surface. If the tunnel were not lighted, the driver could not recognize obstructions in time since he is coming out of bright daylight into the darker tunnel and his eyes are adapted to daylight. Under the given conditions, the contrast sensitivity for seeing into the tunnel may not be more than 1 : 20 or even only 1 : 10 since the high surrounding luminance, compared with that at the tunnel entrance and interior of the tunnel, leads to indirect glare.

Provided that the reflection factor is the same, this comparison can also be made with the illumination. If there is an illumination of 50,000 lux in front of the tunnel, there must therefore be about 5,000 lux in the initial section of the tunnel. Busson [10] has shown that the indirect glare becomes less, however, the nearer the vehicle comes to the tunnel. The ratio between the areas observed increases steadily in favour of the area of the tunnel. The contrast sensitivity is thus steadily improved from 1 : 10 to practically 1 : 100. If one refers these relationships to a point at the limit of the braking distance ahead of the vehicle, it is found that the high illumination in the initial section need not be retained to the same extent further on in the tunnel and may be reduced the further one penetrates into the tunnel (Fig. 6). The illumination is inversely proportional to the square of the angle from which the tunnel entrance is seen and can be derived directly from the Stiles-Holladay glare formula (Fig. 7) [5].

When the driver approaching the tunnel reaches the mouth of the tunnel or when he can only see the latter,

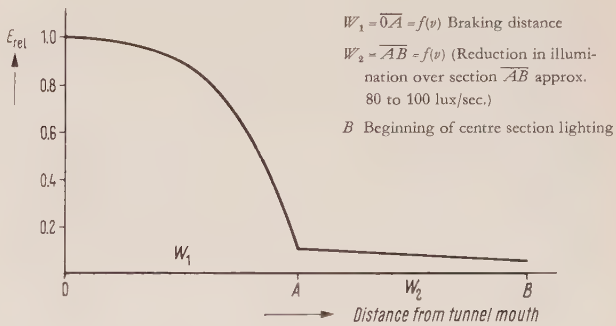


Fig. 6 Relative characteristic of the illumination in tunnel interior (according to Busson)

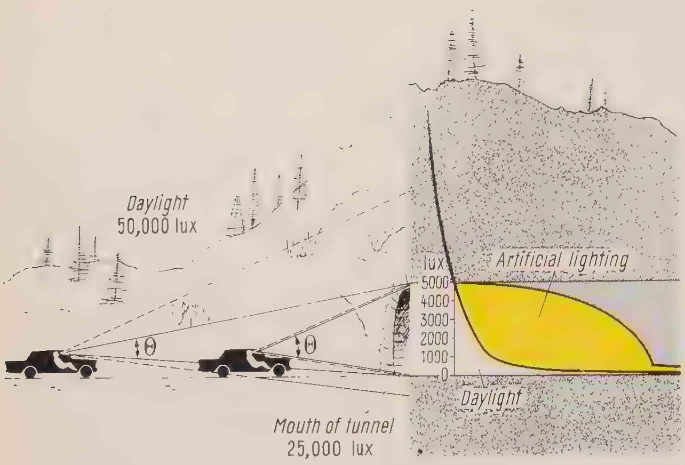


Fig. 7 Influence of indirect glare

proper steps, a ratio of about 0.3 can be obtained between σ_A and σ_J. With daylight of 50,000 lux, therefore, only 5,000 · 0.3 lux = 1,500 lux are required at the tunnel entrance, and no longer 5,000 lux. The relative variation of the illumination towards the tunnel interior is retained, however, and is only a function of the vehicle speed in the two sections $\overline{0A}$ and $\overline{AB}$.

No special steps need be taken for the exit of the tunnel since the eye can adapt itself more rapidly from darkness to brightness than vice versa. If the tunnel has two bores, one for each direction, it is advisable to provide both bores with adaptation sections at both ends.

Vehicular tunnels are best fitted with continuous rows of fluorescent lamps to be installed high up the wall on both sides of the tunnel bore. As in the case of luminaires mounted in the parapet, this eliminates flashing effects.

the indirect glare ceases and the luminance contrast may be once more as much as 1 : 100. Referred to the external illumination of 50,000 lux, an illumination of 500 lux is obtained at the end of the theoretical braking distance measured from the tunnel entrance.

The assumption that the mean reflection factors inside and outside are equal is incorrect. In order to determine the actual illumination required, all the values of the Busson curve can now be corrected with the factor obtained from the relationship between the mean reflection factor outside (σ_A) and inside (σ_J), for the luminances decisive for the contrast sensitivity are directly proportional to the product of illumination and reflection factor.

Actual adaptation sets in only after the tunnel has been entered; the eye adapts itself to the new condition so quickly that the illumination can decrease by about 80 to 100 lux per second without vision being impaired. This always refers to the point ahead of the vehicle at the end of the braking distance. If 100 lux are obtained at this point, adaptation takes place more slowly; from this point onwards the illumination may only decrease by about 30 to 50 lux per second until the value of about 30 lux required for the rest of the tunnel is achieved.

The major problem in tunnel lighting during the daytime is thus the reduction of the difference in luminance inside and outside at the tunnel entrance and the correct grading of the illumination inside the tunnel. In order to keep the expense for artificial lighting within reasonable limits, an attempt should be made to construct an adaptation section before the actual entrance to the tunnel. This can be done in various ways, e.g. by means of a dark road surface and dark side walls before the tunnel entrance or by planting the approach with trees, erecting tunnel portals and louvered surfaces to throw shadows, while the side walls and road surface inside the tunnel should be as bright as possible. If the civil engineer takes the

The higher luminous flux required in the zones of greater illumination at the entrance is easily obtained by adding more continuous rows which can be switched on and off in keeping with the light outside.

The illumination can be controlled by the switching on and off of complete groups of lamps by means of photoelectric lighting control units installed outside the tunnel in the proximity of the tunnel entrances. A time delay feature ensures that the units do not respond and switch off a group merely when a cloud passes over.

The luminaires must be designed to meet the arduous conditions encountered in tunnels. With normal sheet-steel designs, the high degree of humidity often in conjunction with a high salt content leads quickly to corrosion. The luminaires must be totally closed and sealed to prevent the contamination layer caused by exhaust gases and dust from being deposited directly on the surfaces of the lamps and reflectors. Since tunnels may be hosed down and often also cleaned with rotating brushes, the luminaires must also be of hose-proof design.

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Shipboard Antenna Systems for Radio Program Reception

By Erich Heine

Efforts are today made to equip passenger ships to enable passengers and crew members to listen to the radio programs to which they are accustomed when on land. Appropriate antenna outlets are for this purpose installed in cabins and connected to a shipboard master antenna (Fig. 1). Such antenna systems have to operate, however, under more exacting conditions than master antennas serving blocks of apartments. Special antennas, amplifiers, cables and other electrical and mechanical accessories have therefore been developed that are capable of meeting the climatic, mechanical and electrical requirements encountered on board ships.

Fig. 2 is a schematic representation of the layout of a shipboard master antenna system without amplifier for one to eight parties. This model is used on small costal shipping vessels where adequate receiving volume is insured. For larger ships with a great many radio sets and a correspondingly complex distribution network it is necessary to use antenna systems with amplifiers, the basic layout of which is shown in Fig. 3.

Being designed with a flexible glass-fiber rod, the shipboard antenna SAA 108a for LW, MW and SW (1) is fully proof against corrosion and the elements. The signals picked up by this antenna (see Fig. 1) are fed to the tropicalized shipboard antenna transformer SAA 219a (2) for matching the extremely frequency-dependent base-point impedance of the antenna with the characteristic impedance of the antenna lead. The transformer case embodies a glow-gap arrester for protecting the transformer against overvoltages due to the operation of the ship's transmitter. The shipboard antenna lead SAL 414 (3) is designed as a 60-Ω coaxial cable and protected by means of impregnated tape and steel-wire braiding. It is therefore suitable for installation both above and below deck. The antenna arrester (4) is enclosed in a watertight, cast-iron case.

Fig. 4 shows the internal layout of the new shipboard antenna amplifier SAV 350 GW (5), which has a larger frequency range (0.15 to 30 mc) as well as other appreciable improvements as compared with the earlier model SAV 315 GW. The frequency range is realized with two (parallel) pushpull channel amplifiers, whose inputs and outputs are interconnected by means of appropriate filters. One amplifier operates in the range from 0.15 to

Fig. 1 Shipboard antenna SAA 108a with glass-fiber rod

5 mc (LW, MW up to SW) and the other in the SW range (5 to 30 mc). The 1.5 to 5 mc range can be cut out whenever there is danger of the antenna system being overloaded by the high field strength of shore radio stations when the ship is near the coast. External gain controls are provided for the two wavebands to allow adaptation to existing conditions of reception. A further control is provided for the plug-in wavetrap. If necessary to permit radio transmission from the ship, the input of

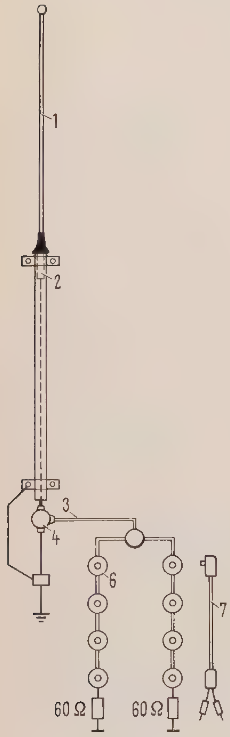


Fig. 2 Layout of shipboard master antenna system without amplifier (for 1 to 8 parties)

1 Rod antenna
2 Antenna transformer
3 Antenna lead
4 Antenna arrester
5 Antenna amplifier
6 Antenna outlets
7 Tropicalized receiver leads

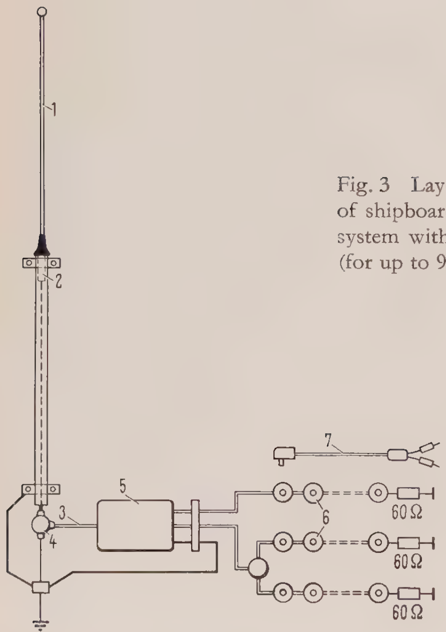


Fig. 3 Layout of shipboard master antenna system with amplifier (for up to 90 parties)

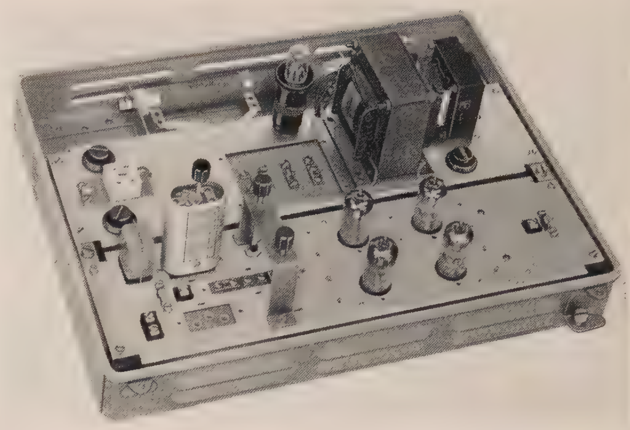


Fig. 4 Internal layout of shipboard antenna amplifier SAV 350 GW for 0.15 to 30 mc

the amplifier can be shorted from the radio operator's cabin by means of a built-in low-voltage relay. The input impedance of the amplifier is matched with the 60 Ω of the antenna lead. As its output impedance is 30 Ω, it can always be connected to two main leads of the distribution network. The gain is about 38 db in the LW and MW ranges, 30 db in the 1.5 to 5 mc range, and 27 db in the SW range. The power supply unit can be adapted for power supply voltages of 110 and 220 v a-c/d-c.

In addition to stress due to jolting and other mechanical impact, the amplifier tubes are also particularly endangered by the vibration of the ship. The amplifier has therefore been given an extremely rugged design and is mounted in a rubber-bonded metal frame. Owing to the use of tropicalized insulating parts and vacuum-impregnated power supply transformers and coils, the amplifier is able to stand up to all climatic conditions.

The two main leads connected to the output of the amplifier run to the antenna outlets (6) in the cabins. For installation above deck it is necessary to use the special shipboard antenna lead SAL 414; for installation below deck the simpler antenna lead SAL 410 is sufficient. Special care is essential when taking the antenna lead through the bulkheads. As a result of the use of high-quality insulating materials, antenna outlets and distribution boxes are tropicproof. The radio sets are connected to the outlets by means of tropicproof receiver leads (7), each of which embodies a transformer for matching the receiver input impedance with the impedance presented by the decoupling elements in the outlet.

These types of shipboard antenna systems for radio program reception have already given excellent service and the new shipboard antenna amplifier with its broad frequency range represents an important advance in this branch of technology.

A Small Welding Transformer with D.C. Biasing Control

By Paul Zwanzger

Small welding transformers are used on building sites and also in trade and industry for occasional welding work of short duration. They are suitable for any work with electrodes of up to 4 mm (0.157 in) diameter or where only power from the lighting system is available. Particular advantages of small sets are their mobility because of their light weight and low cost.

With the small welding transformers previously available the welding current was only adjustable in steps. A finer adjustment of the current is, however, desirable to obtain good welding characteristics especially with electrodes of small diameter. In the development of the small welding transformer LR 4v (Fig. 1), therefore, the method of control by d.c. biasing, which had already proved satisfactory for the larger welding transformers, was adopted.

The most satisfactory form of construction both technically and economically appeared to be the leakage transformer, with a leakage path which could be saturated by d.c. biasing. With this arrangement the drooping current/voltage characteristic is due to the leakage reactance between the primary and secondary windings. As Fig. 2 shows, in the window of the transformer core with one leg wound there is a further small two-leg core, which carries the leakage flux; this flux can be varied by d.c. biasing with the aid of the d.c. control winding (6) on the legs of the leakage core, whereby the welding current can be adjusted to the desired value. The primary winding of the transformer is designed for the two voltages 220 and 380 V. When supply is taken from a 220-V lighting system the welding current must be limited to 100 A with regard to the permissible primary current. The leakage reactance necessary to achieve this is obtained in that the primary winding (1) for the 220-V supply voltage is arranged on the transformer leg only, whereas the secondary winding (5) embraces the leakage core also. At 380 V a much greater power can be drawn from the network and the maximum setting of the welding current can be increased to 180 A. For this purpose, the primary winding is split in such a way that w_1 turns (1 and 2) surround the main transformer core only and the remaining w_2 turns (4) also embrace the leakage core, as does the secondary winding. The leakage reactance is thereby reduced in the ratio $w_1^2/(w_1 + w_2)^2$ and the maximum setting of the welding current is increased accordingly.

The supplementary winding (2) connected in series with the primary winding for 220 V is also used to produce a total voltage of 380 V for the connection of a capacitor to compensate the reactive power. This reduces the primary current, thus enabling the transformer to be connected to the lighting system. At 380 V primary voltage the capacitor is connected directly across the

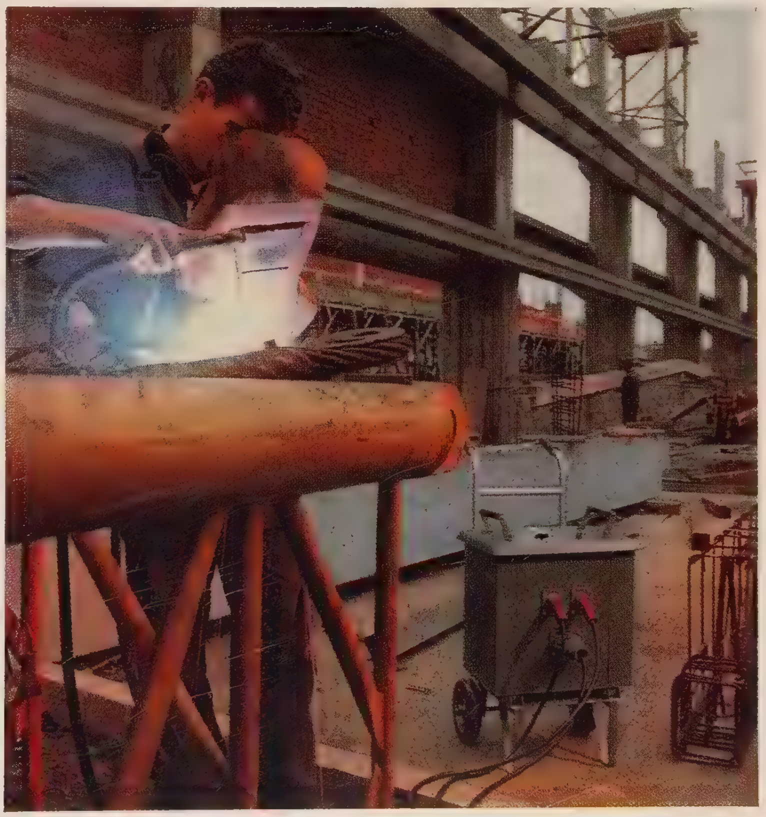
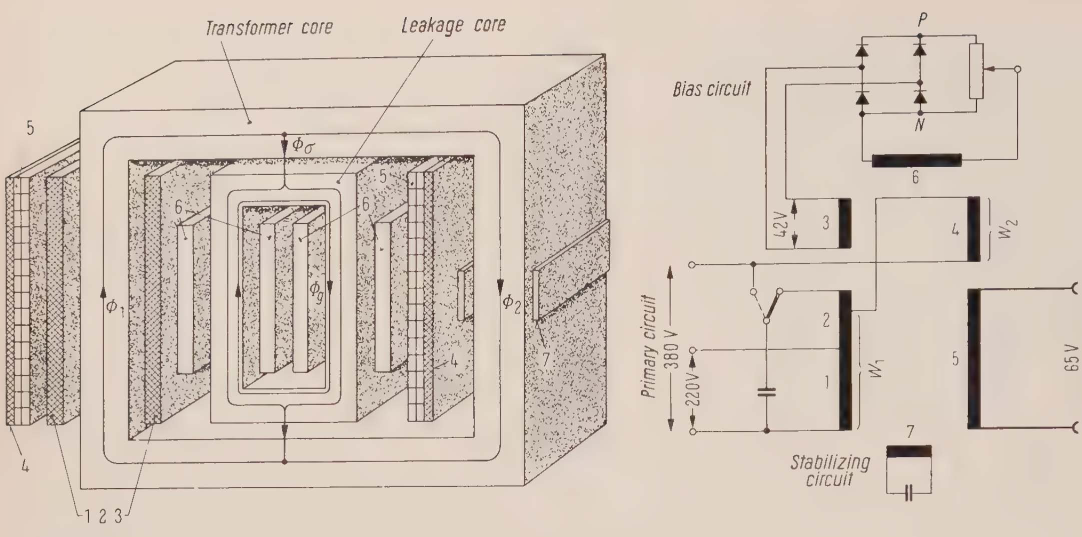


Fig. 1 Arc welding transformer LR 4v



1 Primary winding for 220 V
2 Supplementary section of primary winding
3 Auxiliary winding for 42 V
4 Part of the primary winding embracing the leakage core
5 Secondary winding
6 Bias winding
7 Stabilizing winding

Fig. 2 Basic arrangement and electrical circuit of the welding transformer

input terminals. On the return leg not carrying the main winding is an additional auxiliary winding (7) loaded by a small capacitor, which supplies part of the magnetizing power and thus holds the secondary open-circuit voltage constant irrespective of the amount of bias.

The bias circuit is fed from an electrically separate 42-V auxiliary winding through a metallic rectifier. Stepless adjustment of the current is effected by means of a small, specially reliable potentiometer. By layer-wise series connection of the two bias windings (6) the induced voltages of fundamental frequency and the odd-numbered harmonics are cancelled out within the winding. The current flowing in the control circuit can therefore assume its normal wave form. Even-numbered harmonics are therefore superimposed on the direct current in the manner familiar with current-controlling transductors, whereas only odd-numbered current harmonics flow in the load circuit. To obtain an optimum wave form for arc welding there is an air gap at the top and bottom between the leakage core and the main transformer core. Especially in the case of small welding currents, these air gaps have the effect of increasing the steepness of the curve at the current zero, which assists restriking of the arc.

A particular advantage of the arrangement of core and winding adopted is that practically the whole of the leakage flux, which with arc-welding transformers reaches almost the magnitude of the effective flux, is restricted to the space between the primary and secondary windings. This effectively prevents stray leakage fluxes which may cause eddy-current losses in constructional parts and mechanical vibration.

Fig. 2 also shows the variation of the flux. Φ_1 represents the whole magnetic flux linking with the primary winding, including the leakage flux $\Phi\sigma$. The difference flux $\Phi_2 = \Phi_1 - \Phi\sigma$ is linked with both windings and therefore determines the secondary voltage. Φ_g is the unidirectional flux produced by the d.c. bias winding. The simplified equivalent circuit diagram (Fig. 3) results from the flux distribution, the copper and iron losses being neglected. In this, L_{1h} and L_{2h} represent the main

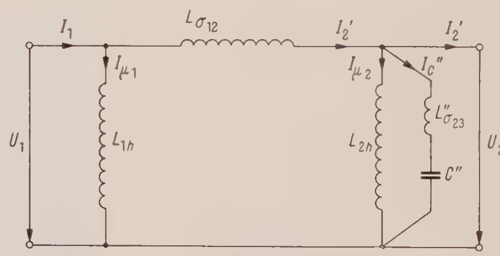


Fig. 3 Simplified equivalent circuit diagram of the small welding transformer

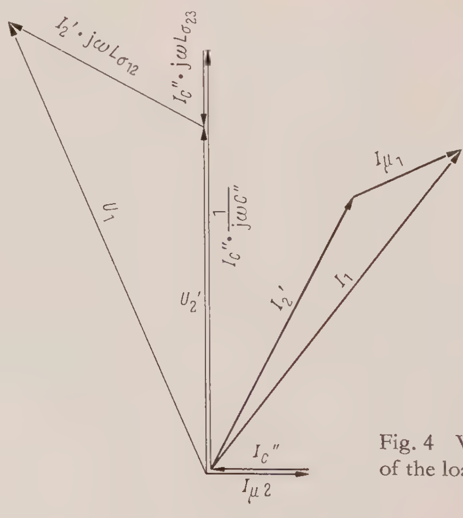


Fig. 4 Vector diagram of the loaded transformer

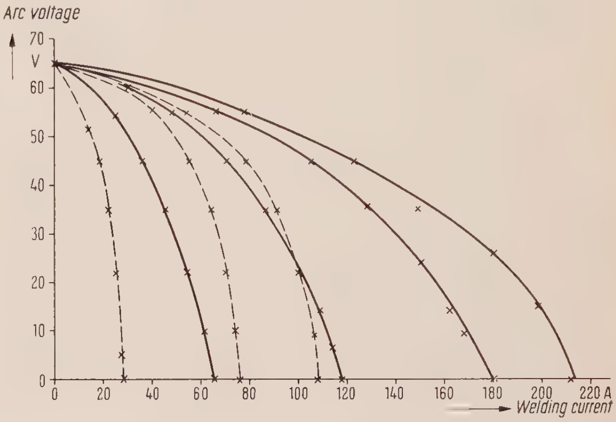
reactances, $L\sigma_{12}$ the variable leakage reactance between primary and secondary windings and $L\sigma''_{23}$ the leakage reactance between the secondary and stabilizing windings related to the number of primary turns. C'' is the capacitance, also converted, of the capacitor connected to the stabilizing winding. The vector diagram for the loaded transformer can then be drawn (Fig. 4). The vectorial sum of the reduced secondary current I_2' and the magnetizing current $I\mu_1$ is equal to the primary current I_1 if $I\mu_2$ is compensated by the capacitive current I_c''. The secondary voltage U_2' is then equal to the difference between the primary voltage U_1 and the voltage drop $I_2'\mathrm{j}\omega L\sigma_{12}$. For given voltages U_1 and U_2' on the other hand, I_2' depends only on the reactance $L\sigma_{12}$ adjusted by the bias. On open-circuit, $U_2'=U_1$ when with a compensated stabilizing winding $I\mu_2+I_c'=0$. This avoids part of the effective flux flowing through the leakage path, so that the secondary open-circuit voltage of 65 V remains constant over the whole setting range. This is the reason for the excellent striking characteristics of the transformer. The dynamic behaviour and the static current/voltage characteristics also fulfil the requirements of arc welding, so that excellent welding charcteristics are obtained over the whole setting range. Fig. 5 shows a family of measured current/voltage characteristics.

When the transformer is connected to the lighting system the welding current is adjustable from 25 to 100 A. With 380 V primary voltage the range is from 50 to 180 A. It is assumed that the working voltages are as standardized in VDE* 0541. With supply from the lighting system and 100 A welding current the permissible relative duty factor is 35%. With 380 V primary voltage and 150 A welding current it is still 25%. The load windings are amply dimensioned and, in addition, are insulated with fibre-glass-silicone compound. They therefore comply with Insulation Class H and are thus relatively insensitive to the overloads which may occur in welding duty.

Fig. 6 shows the core-and-coil assembly of the apparatus. In addition to the outer windings embracing also the leakage core, the inner primary winding can be seen, also the stabilizing winding on the return leg of the core. The components of the control gear comprising metallic rectifier and potentiometer, also a four-pole selector switch for the primary voltage, are separated from the core-and-coil assembly by a plate, which acts as a thermal screen. The two capacitors are also so mounted as to be protected from heat radiation. The plug socket on the apparatus contains a combination of different plug connections with the built-in mains switch suitable for the lighting system or the three-phase network, so that the correct primary supply is always ensured.

The tank is protected against the entry of foreign particles and corresponds to type of enclosure P 21. Notable features are the handy form and easy transportability of the transformer; a truck with solid-rubber tyred wheels can be supplied.

The special advantage of the new welding transformer is the stepless control of the welding current by purely electrical means. Other characteristics of the new apparatus are increased reliability in service and long life as no switching contacts or mechanical adjusting devices are necessary in the welding-current circuit.



——— Primary voltage 220 V ——— Primary voltage 380 V

Fig. 5 Current/voltage chracteristics of the welding transformer

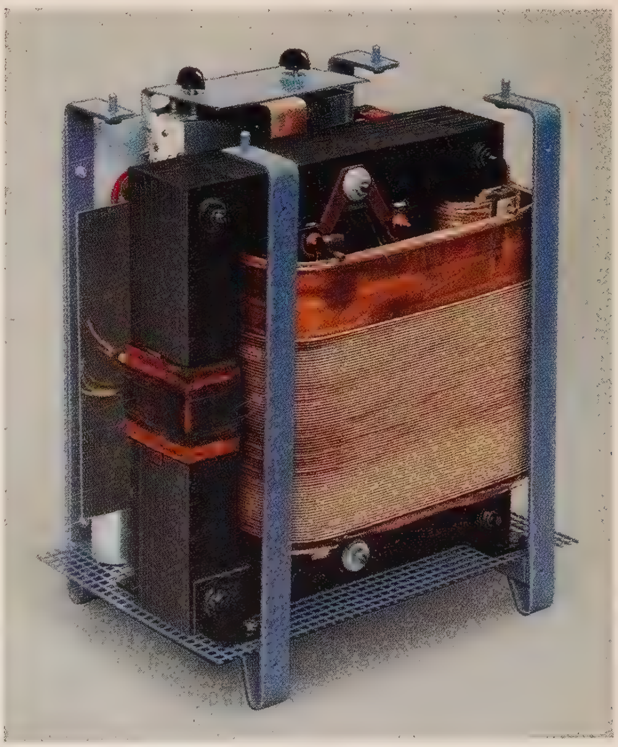


Fig. 6 Arc welding transformer LR 4v, cover removed

* VDE Association of German Electrical Engineers

Type BU Fixed-Time Controllers for Traffic Signal Installations

By Heinz Benzinger

The function of a traffic signal installation is to secure the safe and speedy flow of dense highway traffic. The capacity of signal-controlled intersections depends largely on whether and to what extent the control equipment used can be adapted to changing traffic conditions. Various types of control equipment are chosen according to local conditions and the composition, direction and density of traffic. Single intersections are usually assigned either fixed-time controllers (automatic control) or vehicle-actuated control units (automatic adaptation of sequence and length of individual phases to traffic conditions by, say, treadle vehicle detectors, trolley-wire contacts, pedestrian pushbuttons); highways with many intersections are usually controlled by a progressive-type system of interconnected traffic signals; for a highway network covering an entire district or city recourse is taken to a progressive centrally controlled system. Fig. 2 shows the various methods of traffic control commonly used for areas of different size.

Fixed-time control: control in individual phases

Up to a few years ago it was common practice to process the traffic across an intersection in a certain number of phases, one or more streams of traffic being assigned right-of-way while conflicting streams were held up. After a fixed period the streams of traffic that had been given right-of-way were held up and right-of-way then assigned to the other streams that had been kept waiting. The traffic-handling capacity of a strictly orthodox phase system such as this depends primarily on the number of phases; the length of time that a stream of traffic is held up depends on the number and length of the stop phases allocated for traffic in this particular direction. This is why, as a rule, only 2- to 4-phase controllers were used. With this method, however, the adaptability of the control equipment to changing traffic conditions was greatly restricted.

New approach of BU system: independent control of signal groups

The drawback of orthodox phase control was overcome – in isolated cases at first and then to a steadily increasing extent – by assigning several orthodox phase control systems to an intersection and securing optimum adaptation by staggering their interval times. For controlling highways with a great many intersections or an entire

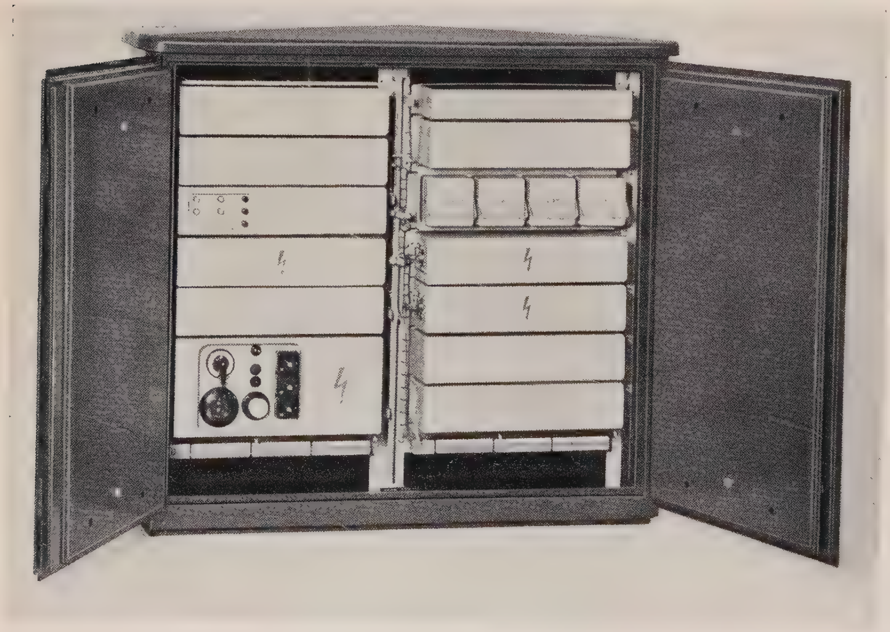


Fig. 1 Type BU fixed-time controller (fully equipped) with plug-in program feature

highway network this yielded the further advantage that the time intervals from intersection to intersection demanded by the progressive control system could be observed without reducing the traffic-handling capacity of the individual intersections.

With its type BU controllers, Siemens & Halske have gone one step further: instead of the traffic being processed in phases, the various signal groups* at an intersection are controlled independently. This gives the traffic engineer complete freedom in the handling of traffic: the interval starting points of the individual signal groups can be fixed without reference to other signals. (This, of course, does not preclude the use of special timing arrangements to avoid situations that would endanger traffic.)

Design and operating principle of controllers

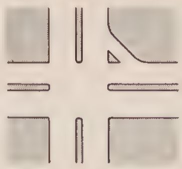
The BU controllers are designed on the unit construction principle, their various units being plugged together. Any work that may be necessary on the equipment is therefore extremely simple to perform and subsequent modifications, or, in particular, expansions, are readily possible. For reconditioning and checking, or in the event of faults, the various plug-in units can be individually exchanged without difficulty.

Fig. 3 shows the schematic layout of a controller and a signal control scheme. Under normal conditions a pulse generator emits a pulse every second that is applied to a timer. The connect and disconnect windings of the signal group relays are connected to the timer by way of program selectors. The contacts of these relays control the incandescent lamps in the signal heads. The jumper wires can either be soldered on or plugged in with jacks. This jumpering, which can be arranged as required for each program, allows the adaptation of the equipment to the given traffic conditions. The number and sequence of the interval starting points for switching the aspects of the various signal groups can be changed from program to program. This is, in fact, a basic traffic engineering requirement that is having to be met more and more in fixed-time control applications.

Major potentialities

Depending on the traffic conditions to which the controller is to be adapted, it can be equipped with one, two, or three control relay sets according to system design. Six signal groups for vehicles, or two for vehicles and eight for pedestrians, or four for vehicles and four for pedestrians, can be assigned to each control relay set. As it has been found that the on/off switching of a system during a green aspect (mostly in the main direction) and a red aspect (secondary direction) is liable to involve certain difficulties, an optional attachment has been designed for the BU controllers that effects on/off switching during an all-amber interval.

* A signal group is represented by a group of signal units that always display the same signal at the same time.

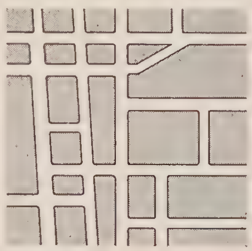


Single intersection

Individual control:
1. Control by traffic policeman
2. Manual operation of traffic signals
3. Fixed-time control
4. Semi-traffic-actuated control (phase cycle on demand)
5. Fully traffic-actuated control (automatic adaptation of sequence and length of individual phases to traffic conditions)

Highway with many intersections

Group control:
1. Progressive fixed-time control
2. Progressive fixed-time control with semi-traffic-actuated option
3. Traffic-actuated modification of progressive fixed-time control ("flexible progressive system")



Traffic network

Central control:
1. Progressive fixed-time control
2. Progressive fixed-time control with semi-traffic-actuated option
3. Traffic-actuated modification of progressive fixed-time control ("flexible progressive system")

Fig. 2 The various types of traffic control for the individual control areas covered by traffic signal installations

In order to cope with changes in traffic conditions as a function of the time of day, the controllers are adapted to operate with up to four programs. Any program can be changed at any time by pressing the appropriate program button. The switching pulse is stored until the controller reaches what is termed the "favorable switching point", which is the time when all the signal heads display a certain aspect that is present in all programs. The switching of programs at this instant insures that the signal heads will neither jump a color nor display a wrong sequence of signals.

Customers sometimes specify that even complex control equipment should be designed to allow the manual switching of signals whenever necessary as the result of a road accident or unforeseeably dense traffic. It is, however, practically impossible for an operator to keep an eye on or actively control the individual interval starting points and signal aspects from a control point in the event of heavy traffic. It sometimes occurs, for instance, that from 30 to 40 different interval times fall within a single phase cycle. In such cases it is therefore necessary to cut in a manual switching program. This should, of

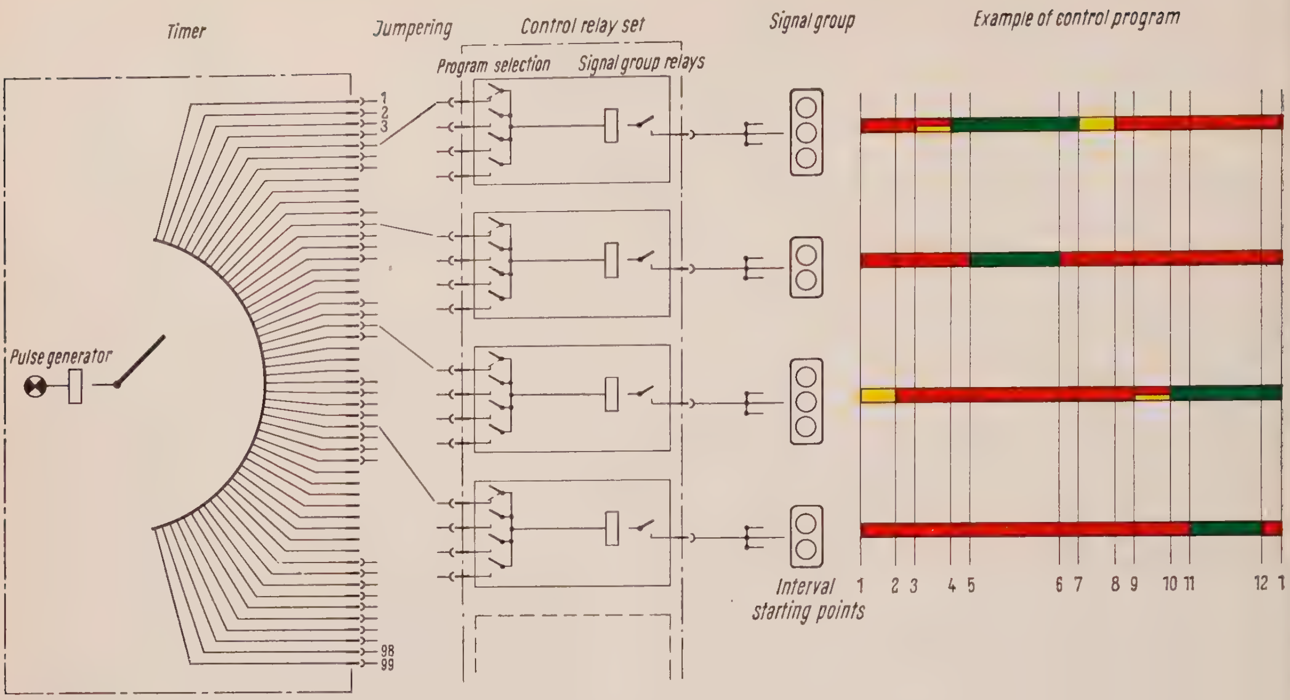


Fig. 3 Schematic layout of type BU fixed-time controllers with a traffic control scheme for two vehicular signal groups and two pedestrian signal groups

course, be based upon a simple traffic control scheme such as would be used in an orthodox phase control system.

Attachments can be added to adapt the equipment to allow the group control of interconnected intersections (progressive traffic control). A single pair of wires (loop) is sufficient to establish the interconnection. Each controller is provided with a unit for receiving on/off and program switching signals from a higher-ranking progressive control panel. A monitoring circuit prevents these control signals from taking effect unless they are properly received without distortion by all controllers. The timers of all controllers are synchronized during each phase cycle. Minor deviations of timing are automatically corrected, while major deviations require the withdrawal of the respective timer from the synchronizing process; despite this, the controller involved will continue to function as an independent unit. The fault is indicated at the control point. The progressive control panel itself should, where possible, be accommodated in one of the controllers.

If a low-traffic route at an intersection is to be assigned right-of-way only on demand, the controller can be equipped with an attachment for traffic-actuated control. Another form of actuation on demand is found where, for instance, buses or streetcars have to be assigned right-of-way while other traffic is held up. In this and similar cases considerations of traffic-handling capacity will disallow the inclusion of a separate bus or streetcar phase (including clearance intervals) in every cycle if experience has shown that such a demand will occur, say, only after every five cycles. The BU controllers offer a very simple solution to problems of this category: whenever a demand occurs, a special cycle is cut in that is executed during the normal cycle as a function of the traffic conditions. Following the completion of the special cycle, the controller automatically reverts to its normal program until the arrival of a new demand calls for the execution of another special cycle.

The controllers are equipped with a signal monitoring feature to prevent signals from being given that would hazard traffic safety (e.g. failure of a red lamp governing the main traffic route or wrong connection of signal circuits). A trouble indication is originated whenever a fuse blows or the signal monitor is tripped. Automatic disablement of the system in the event of trouble is possible.

The controllers can be operated either manually or by a switching clock, and are provided with terminals for the connection of a switching clock or to allow remote control.

In summary it may be said that BU fixed-time controllers are suitable for use both at simple and highly complex intersections, and particularly in cases where traffic conditions demand extreme flexibility from control equipment. Attachments are available with which the controllers can be linked for the progressive group control of interconnected intersections. The unit construction principle facilitates work on the equipment and readily permits subsequent expansion.

Advantages of Marine Cables with Butyl Rubber Insulation

By Horst Hübner

The rapid development of electrical engineering in marine applications has resulted in an appreciable increase in the rating of the electrical machines and apparatus employed. This has in turn led to more extensive cable systems on ships. On a modern freighter, for instance, the electrical equipment constitutes a considerable percentage of the total tonnage. For this reason, shipbuilding firms demand that cables shall be low in weight and have a small diameter. Apart from making a saving in weight, lighter cables are easier to handle and reduce the time required for installation. Entry of the cables into equipment, drives and switchboards, etc., is also made easier (Fig. 1).

With few exceptions, marine cables are now provided with lead sheaths which protect the cable core assembly against the ingress of moisture. Reasons associated with safety did not appear to make it advisable to replace lead-sheathed cables by synthetic-rubber-sheathed cables for all applications. There are other reasons which speak against this. Although non-metallic-sheathed cables are lighter than lead-sheathed cables, they are not thinner and thus require the same amount of space; in some cases they are also more expensive. Consequently, they have not found general acceptance in the shipbuilding industry.

The demand for thinner, space-saving cables for the construction of merchant ships can, at present, only be met by higher loading of the conductor. Higher loading is, however, accompanied by higher conductor temperatures, for which in turn insulation with higher resistance to heat is required.

For a long time cables have been available with insulation consisting of varnished cambric tape. These varnished cambric cables are approved by Lloyd's Register of Shipping and conductor temperatures of up to 80°C are permitted. They are thus capable of carrying higher loads than the conventional rubber-insulated cables (conductor temperature permitted by Lloyd's Register of Shipping 51°C, by German Lloyd 60°C). The fact, however, that the insulation of varnished cambric cables is sensitive to moisture has certain disadvantages. Waterproof sealing ends have to be provided, even where the cables terminate in equipment and the cores are protected. In the case of small and medium cross-sections, the price is very high compared with other types of marine cables. In Germany therefore varnished cambric cables are not commonly used.

Endeavours were made to find more suitable insulating materials which retain the properties of the conventional rubber insulation and yet have a higher resistance to heat. These requirements are met by heat-resistant PVC compounds, which are also used sometimes for marine cables, and by butyl rubber, a copolymer of polyisobutylene and isoprene. Butyl rubber is vulcanized in exactly the same manner as natural rubber and is likewise flexible. It is distinguished from natural rubber by appreciably lower water absorption and a high degree of imperviousness to gases and water vapour. Marine cables insulated with butyl rubber therefore provide greater electrical reliability than natural rubber or varnished cambric cables when exposed to the effects of moisture. The electrical properties are equivalent to those of good natural rubber compounds.

The resistance to aging of butyl rubber is much higher than that of the conventional natural rubber compounds. Since butyl rubber has a high creep rupture strength and

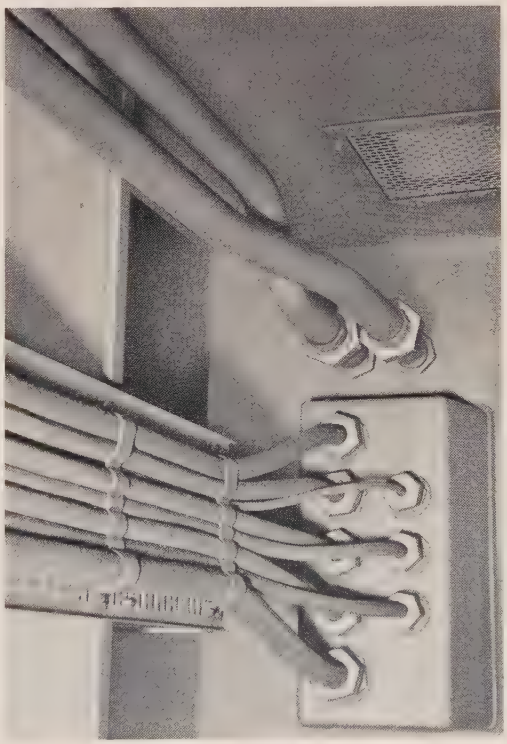
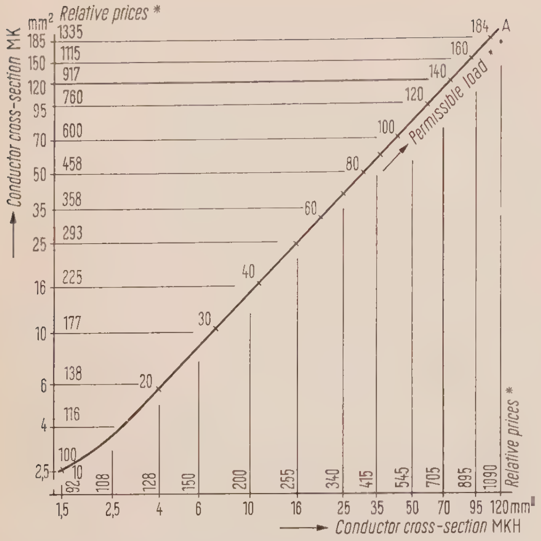


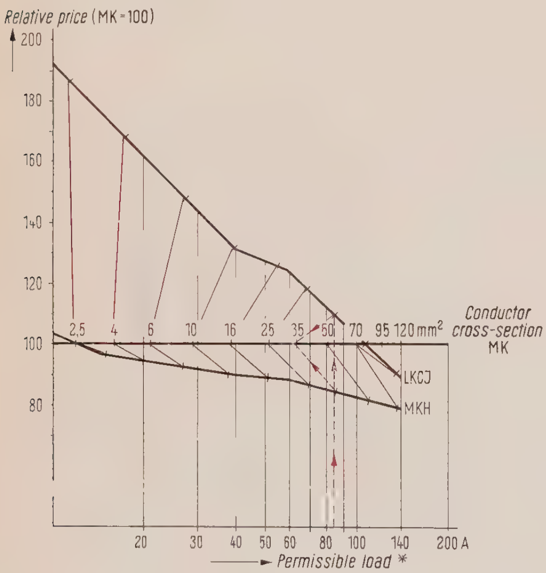
Fig. 1 Waterproof bulkhead bushings for marine cables



MK Cable with natural-rubber insulation
MKH Cable with butyl-rubber insulation
* The prices are referred to MK 3 × 2.5 mm² (taken as 100%).
** Continuous operation, six cables grouped together, ambient temperature 45 °C (to DIN 89150)

Example: For a load of 135 A a cable of the type 3 × 120 mm² MK is required (relative price 917) or a cable of the type 3 × 70 mm² MKH (relative price 705)

Fig. 2 Cross-sections of equal capacity and relative prices of three-core marine cables with a lead sheath and steel wire braiding (1 mm² = 0.00155 sq. in.)



MK Cable with natural-rubber insulation
MKH Cable with butyl-rubber insulation
LKCI Cable with varnished cambric insulation
* Continuous operation, six cables grouped together, ambient temperature 45 °C
Conductor temperatures: MK 60 °C in accordance with DIN 89150
MKH 80 °C in accordance with DIN 89150
LKCI 80 °C in accordance with Lloyd's Register of Shipping

Example: For a load of 85 A a cable of the type 3 × 35 mm² MKH is required or a cable of the type 3 × 70 mm² MK or 3 × 35 mm² LKCI. Here the cable prices have a ratio of 83:100:108

Fig. 3 Relative prices of three-core marine cables as a function of the permissible load (1 mm² = 0.00155 sq. in.)

high tensile strength, even at high temperatures, the continuous permissible conductor temperature was fixed at 80°C on the basis of certain foreign standard specifications and in agreement with the Classification Societies. This temperature is 20°C higher than that permitted by German Lloyd for natural-rubber-insulated marine cables and 29°C higher than that for rubber-insulated marine cables specified by British Lloyd. At the present time there appears to be no need to permit conductor temperatures higher than this.

A comparison of the current-carrying capacities of single-core lead-sheathed marine cables shows that for the same loads the cross-section of butyl-rubber-insulated cables is smaller than that of natural-rubber-insulated cables, this being by one standard size up to a conductor cross-section of 95 mm² and by two sizes for cross-sections greater than this (see Figs. 2 and 3). Under favourable conditions it is in fact possible to select butyl-rubber cables two sizes smaller at cross-sections below 95 mm². If, for instance, a single-core cable is to be selected for a load of 100 A, a cross-section of 50 mm² would be required (in accordance with German Industrial Standards DIN) for marine cables such as MK cables with steel wire braiding over the lead sheath. This cable has an overall diameter of 18 mm. In the case of cables of the same construction but with butyl insulation, for instance MKH, a cross-section of 25 mm² suffices which is two sizes smaller. The diameter of this is 14.5 mm. The conditions obtaining with three-core cables are similar. Butyl-rubber insulation makes possible much thinner and lighter cables.

In addition to this, butyl-rubber cables may afford advantages in price. Although butyl-rubber cables are more expensive than natural-rubber-insulated cables of the same cross-section and core number, they are in some cases appreciably cheaper if compared on a basis of current-carrying capacity. The curve in Fig. 2 shows cross-sections of equal current-carrying capacity together with the particular rating. The current-carrying capacity is based on a conductor temperature of 60°C for natural rubber and 80°C for butyl rubber in accordance with DIN specifications 89150 of German Lloyd.

If account is taken of the fact that Lloyd's Register of Shipping at the present time permits a conductor temperature of only 51°C (124°F) for natural-rubber-insulated cables, it will be seen that the saving in cross-section and price is even greater.

Fig. 3 shows as a function of the load the relative prices (MK = 100%) of natural-rubber-insulated MK cables, butyl-rubber-insulated MKH cables and varnished cambric LKCI cables with a lead sheath and steel wire braiding. From this it can be seen that varnished cambric cables are not as competitive in price as butyl-rubber cables and that in some cases they are also less favourable

than MK cables. Varnished cambric cables afford neither technical nor economical advantages; they can therefore be replaced by butyl-rubber cables.

Of the conventional marine cable types, butyl-rubber cables are at the present time the most advantageous both technically and economically. They have a higher current-carrying capacity, and are lighter and cheaper than natural-rubber and varnished cambric cables. In addition to this, they are simpler to install.

The fact that customers are changing over to the new type of cable is indicated by the orders received. These are rising steadily while in the case of conventional cable types, particularly varnished cambric cables, they are decreasing.

New D. C. Machines of Series G 2

By Rudolf Höppner

The development of electrical drives since the turn of the century is characterised by the transition from d.c. to three-phase a.c. drives. Its low price, reliability in operation and extremely low maintenance costs constituted a clear economic advantage of the three-phase squirrel-cage motor over the d.c. motor. The d.c. motor has, however, held its own and has, indeed, regained ground in the last two decades wherever its special features – great speed and torque adaptability, i.e. wide-range speed control, in fine steps or even steplessly – cannot be matched economically by three-phase a.c. motors. Particularly in the production processes of the various branches of industry, the demands made as to the variability of the drive speeds increase constantly, owing to the progress of automation and rationalisation, i.e. more and more precise, fast and comprehensive control is called for, and this in turn leads to a steady increase in the demand for high-grade d.c. motors.

To meet these requirements of industrial drives, the Elektromotorenwerk of Siemens-Schuckertwerke in Bad Neustadt (Saale) has developed a new series of d.c. machines of Series G 2, with outputs ranging from 0.18 to 2.2 kW at 1,450 r.p.m. This new series constitutes the downward extension of the d.c. machine series G 9, with ratings from 2.7 to 38 kW, newly developed some years ago by the Nürnberger Maschinen- und Apparatewerk.

In the development of new machine series, the weight per kilowatt of power delivered, the so-called weight per unit output, has been steadily reduced. Attention was paid at the same time to obtaining good performance, low maintenance requirements and a wide and stable control range, so that the machines should be well-suited to control and regulation tasks. Without reduction of the rated output, the speed of all motors can be regulated upward in the ratio 1 : 1.5 to 1 : 2 by weakening the field, and, if the rated output is slightly reduced by about 10%, even to 1 : 3, the highest speed that can be set being about 4,500 r.p.m. To keep the influence of the armature reaction small, a large air gap and a special form of pole shoes were selected for these new machines. In the case of all motors whose speed is regulated up to 1 : 1.5 by weakening the field, the otherwise essential auxiliary series winding with its speed stabilising effect can thus be dispensed with. This frequently results in the circuit being simplified, e.g. in reversing operations. With the aid of commutating poles, good commutation and a long service life of the brushes are achieved even for the smallest machines and where operating conditions are severe.

The speed of most d.c. motors used in industry is varied by changing the armature voltage. In the U.S., according to an American statistic, about 90% of all d.c. motors in the medium output range are already speed-controlled by changing the supply voltage. This enables speed ranges of 1 : 30, and, by using special devices, even markedly higher ratios to be achieved. If small speeds are to remain set on fan-cooled motors in continuous operation, the torque must be reduced. For instance, for speed control at constant torque down to half the rated speed of motors with a rated speed of 2,850 r.p.m., the necessary reduction in output, referred to this speed, is only about 7%; for a motor with a rated speed of 1,450 r.p.m., it is about 17%. For short periods, a fan-cooled motor can also yield the rated torque at low speeds. Particular attention has been paid in the case of all motors to faultless operation at very low speeds,

D. C. motor, G 527–2, 1.1 kW, 1,450 r.p.m.

without undesirable torque pulsations and the noise that may ensue.

For the motors, the standard rated voltages of 110, 220 and 440 V apply; for the generators 115, 230 and 460 V. Motors for much lower or higher voltages – up to 500 V – can also be built, however. All motors are suitable for connection to voltages with a relatively high harmonic content such as occur when feeding in is effected via rectifiers.

As, in modern drives, the field is frequently fed from rectifiers, magnetic amplifiers, thyratron or transistor equipment, the excitation required has been kept deliberately low. If the output of the machine is reduced to a certain extent, the excitation can be lowered still further.

In modern drives, good dynamic operating properties are as important as wide control ranges. Particular attention was accordingly paid to obtaining a small moment of inertia in all motors. Together with a small excitation time constant and the measures to reduce the armature reaction, this results in very short acceleration times and low losses, which in turn permits of a greater frequency of starting. Motors up to a rated output of 1.1 kW can be started direct without special measures.

Basic radio interference suppression is obtained for the machines by symmetric connection of the commutating-pole winding on both sides of the armature. It is possible to achieve further suppression to the radio interference degree N according to VDE 0875/12.59 by connecting an anti-interference capacitor, which is housed in the bearing shield of the motor.

Because the insulation is of particular importance for the electrical and thermal safety of the machine, the insulation class A hitherto generally customary has been replaced in the new series by high-grade varnished wires of insulation class E. The insulation is moreover designed to be tropic-proof. All metal parts subject to corrosion are finished with a protective varnish; the terminal boards consist of a moulded material which is unaffected by damp and mould; the brass parts are resistant to stress corrosion. This enables the d.c. machines to be used in practically all climates and all atmospheres. The insulation can also be adequately protected by special design, as experience has shown, against severe strains put on the winding insulation by, e.g., the direct effects of oil and conducting condensation, danger from termites or the incidence of vibrations.

In the design and mechanical construction, too, the latest experience has been taken into account. The same dimensions have been chosen for the shaft heights and feet as apply for three-phase a.c. motors according to DIN 42673. The shaft ends are related to the outputs according to DIN 42946. These two DIN Regulations take into account the IEC Recommendation 72-1, 3rd Edition 1959. Externally, the smooth cylindrical design of the machines gives them a pleasing and modern appearance (see illustration).

Modern drive engineering calls for ever closer connection between the motor and the driven machine. The motors are therefore available in all customary footing and flange designs, so that they can easily be adapted to the driven machine or to space conditions at the point of installation. Certain changes to improve this adaptation can also be made at site. Thus, the terminal box can be turned through 90° and 180°, or transferred to the other side of the motor. Moreover, the design of the motors without condensation drains and the use of bearings which can take the weight of the rotor, including one half of the coupling, in tilted positions as far as the vertical facilitate the subsequent use of a footing or flange design in one of the many possible varieties.

Special attention has been paid to the ventilation of the machines. The generous dimensions of the air inlet and outlet openings, well laid out air paths within the machine and a fan suitable for both directions of rotation provide thorough air cooling. The bearing shields can be turned to adapt the air inlet and outlet to the conditions at the place of installation.

The machines are splash-proof according to DIN 40050 type of enclosure P 22 and thus have the best type of enclosure for protected machines. They are protected at the same time against the penetration of medium-sized solid foreign bodies. The best possible type of enclosure for the terminals of electric machines – P 44 – has been chosen for the terminal boxes. They accordingly afford protection against harmful dust deposits in the interior and against water jets.

In addition, the bearings are sealed against the penetration of dust and water from the outside. The anti-friction bearings produce a minimum of noise and vibration. To increase quietness of operation, they are axially prestressed by a spring washer. The bearings have pre-lubrication, i.e. the grease filling is sufficient for several years' normal operation before it has to be renewed. All points on the machine which it must be possible to reach in the course of operation, such as brushes and brushholders in the commutator compartment, the terminals in the terminal box, and the shaft end on the non-drive side (for measuring the speed) are readily accessible.

The machines are available as shunt-wound, series-wound or compound-wound motors, and as externally excited generators. Apart from this, they are manufactured in all types required, be it as motors or as generators, including totally enclosed motors without surface cooling in the highest type of enclosure for electric machines, P 33. These totally-enclosed motors are distinguished for their smooth casings, to which fibres will not adhere, and enable their speed to be varied over a very wide range by changing the armature voltage, at constant torque and in continuous operation, without any additional decrease in output.

NEW EQUIPMENT

Transformers for High-capacity Carbide Furnaces

By Alfons Sauer

The increasing demand in the chemical industry for calcium carbide, a key product of plastics chemistry, has led to the construction of bigger and more economical furnace units. However, the requirements to be met by the associated transformers have increased to the same extent.

Particularly difficult problems are encountered in the power supply of furnaces of rectangular construction whose electrodes are arranged side by side in one plane. The phenomenon of a high current asymmetry between the three electrodes kown to the operator as "live" and "dead" phases must be able to be balanced as far as possible by separate regulation of the phase voltages at the furnace transformer.

The Siemens-Schuckertwerke have already supplied seven of the furnace transformer units described (see illustration) to large chemical plants in Russia and Eastern Germany.

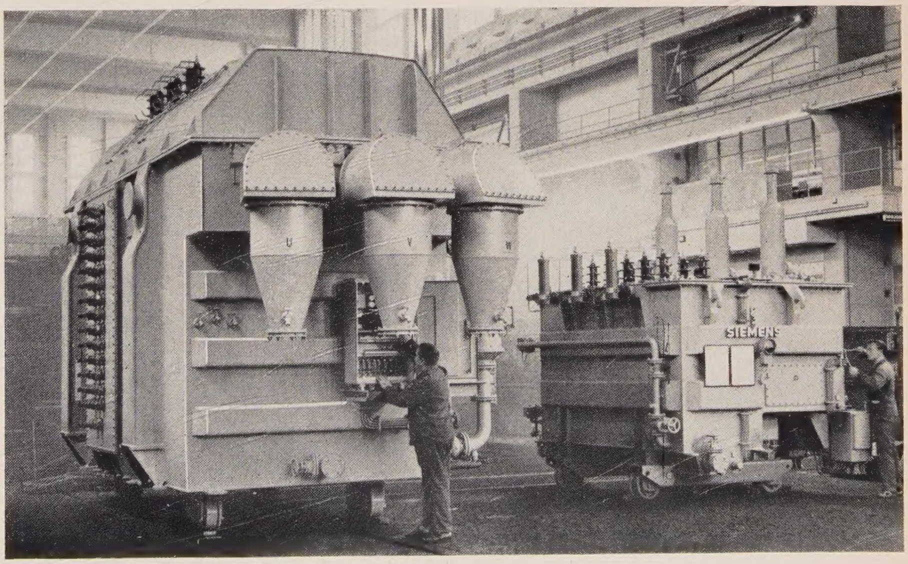
The customers had specified a furnace with a maximum power input of 60 MVA to be connected directly to a system voltage of 110 kV via a transformer whose secondary voltage can be regulated from 290 to 130 V under load. In the range specified, the secondary current of 120 kA per phase must remain constant, i.e. the output must decrease in proportion to the secondary voltage. In addition, the secondary voltage in each phase must be able to be regulated separately, namely up to a maximum difference of 100 V between the highest and lowest voltage in two phases.

30 and 110 kV were first considered for the primary voltage. The decision in favour of the latter and higher voltage was made for the following reasons: With 110 kV the effect of furnace operation on the supply system is less pronounced owing to the higher capacity of this system. The power transformer for stepping down to the intermediate voltage could also be omitted since the existing 30-kV system would no longer have been strong enough. This brought with it an improvement in the overall efficiency of the plant.

To meet the requirements a three-phase transformer with voltage regulation in the intermediate circuit[1] and secondary winding connected in star had to be chosen. Delta connection of the secondary with, at the same time, a delta primary make separate regulation of the phase voltages impossible since the secondary voltage vector diagram would no longer close as a result of the phase angles imposed by the system. Owing to the resulting high circulating currents it is no longer possible to regulate the phase voltages separately. Direct voltage regulation by cutting turns of the primary winding in and out cannot be carried out owing to the high system voltage (110 kV) and the wide range. If three single-phase transformers were to be used instead of a three-phase transformer, the secondary star point for 120 kA would have to be formed relatively far from the transformers – if necessary even at the furnace – owing to the strong transverse magnetic fields, so that six 120-kA high-current leads would then have to be run. This, however, is uneconomical and also leads to high copper losses.

Of special interest in the case in question with the intermediate circuit regulation[1] is the fact that the star-connected auto-transformer is accommodated in a separate tank. This gives the actual furnace transformer – consisting of a main and auxiliary transformer in a common tank – a simple and rugged construction. Should the auto-transformer break down, which is possible due to the fact that it has many moving parts and is therefore subject

1 Rosenthal, W.: Ofentransformatoren. Siemens-Zeitschrift **34** (1960) pp. 96 to 104



60-MVA three-phase furnace transformer (left) with separate regulating auto-transformer (right) for 110-kV system voltage.
The secondary voltage can be regulated between 290 and 130 V at 120 kA

to wear and requires careful maintenance, the furnace can be operated with the main and auxiliary transformers alone, though only at 290, 210 and 130 V. This reduces the expense for replacements since a spare need only be available for the auto-transformer.

The current in the intermediate circuit is always proportional to the secondary current. The high furnace current can therefore be readily measured by connecting current transformers into the intermediate circuit. An intermediate circuit current of 532 A, for instance, corresponds to a furnace current of 120 kA. The voltage in the intermediate circuit is 10,550 V.

The primary winding can be changed over to delta or star by means of a built-in, manually-operated tap changer. In star connection a further voltage range of 167.5 to 75 V is obtained for starting the furnace.

The main transformer is designed for the direct connection of 110-kV single-conductor oil-filled cables. Toroidal current transformers are incorporated in the cable entry boxes for measuring the primary current.

On the secondary side, the furnace current (120 kA) leaves the transformer through 14 water-cooled copper-tube connections per phase. The bends are flexibly connected to the secondary winding and are brought out through an aluminium plate oil-tight and insulated on one of the transformer walls. The secondary star point is brought out to another two copper tubes and can be loaded with 10 kA, for instance, by an electrical furnace tapping device.

Cold-rolled steel sheets with low losses were used for the iron cores. The main and auxiliary transformers have five-limb cores, firstly to achieve a small overall height and secondly to provide a magnetic return path in the case of asymmetric excitation due to separate regulation of the phase voltage.

In the case in question also forced-oil circulation with water cooling preferred for furnace transformers was employed, otherwise the construction is to a large extent similar to that of normal distribution transformers. The same applies for the protective and supervisory equipment.

The furnaces equipped with the transformers described are probably not the last step in technical development. There are many indications that furnace sizes will continue to be increased and the Siemens-Schuckertwerke have already taken steps to deal with such a development.

MISCELLANEOUS

Inductive Field Regulator for D. C. Motors in the Textile Industry

By Erich Goppert

For the control of individual and sectional d.c. drive motors, Siemens-Schuckertwerke have developed an inductive field regulator which is a combination of a normal induction regulator and a set of silicon rectifiers[1].

In the case of the conventional field regulators with a limited number of resistance stages, the control is in many instances too coarse and the permissible frequency of setting operations low owing to wear and tear on contacts. These disadvantages are obviated by the inductive field regulator which permits smooth, stepless and contactless control at any required frequency of operation without wear of parts. At the same time the dimensions of the inductive field regulator can be kept to a minimum by reason of the low losses – it is about an eighth of the size of a comparable metalclad field rheostat. The inductive field regulator is designed with feet and a mounting flange thus providing a variety of possibilities for fitting it to the driven machine.

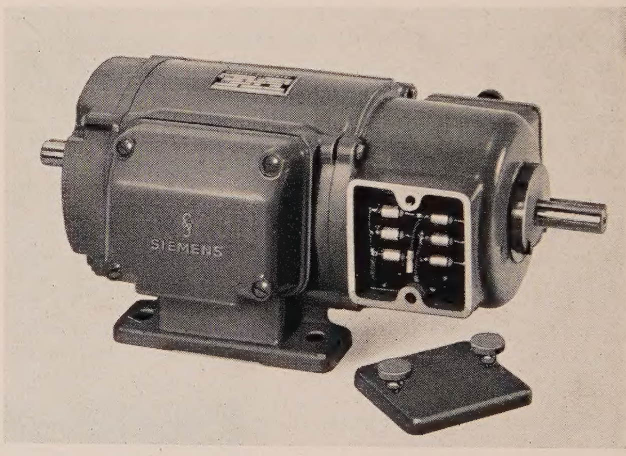


Fig. 1 Inductive field regulator with built-in silicon rectifiers (cover removed) for controlling the field of d.c. motors with outputs up to approximately 15 kW. The data of the regulator are as follows: Input 120 V, 50 c/s; output 80 to 240 V d.c.; circuit rating 600 VA

1 Opitz, W.: Drehtransformatoren als induktive Feldsteller für Gleichstromantriebe in der Textilindustrie. Spinner und Weber 77 (1959) pp. 892 to 894

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